Aspen Management for the 21st Century

DEDICATION

These proceedings are dedicated to those professionals whose research has laid the groundwork for the aspen management practices that are now being applied or developed in Canada. In particular the work of J. Jarvis, J. Maini, G. Steneker, and R. Waldron has provided a foundation on which we continue to build today.

Cover art by Dennis Lee

ASPEN MANAGEMENT FOR THE 21ST CENTURY

**Proceedings of a symposium held November 20-21, 1990,
in Edmonton, Alberta, in conjunction with the 12th annual meeting
of the Poplar Council of Canada**

**Symposium sponsored by:
Forestry Canada, Northwest Region
Alberta Forestry, Lands and Wildlife
Poplar Council of Canada**

S. Navratil and P.B. Chapman, editors

**Joint publication of
Forestry Canada, Northwest Region and Poplar Council of Canada
Edmonton, Alberta
1991**

Funded in part by:
Canada-Manitoba Partnership Agreement in Forestry
Canada-Saskatchewan Partnership Agreement in Forestry

Catalogue No. Fo42-165/1991E
ISBN 0-662-19036-X
Copies of this report are available at no charge from:

Forestry Canada
Northern Forestry Centre
5320 - 122 Street
Edmonton, Alberta
T6H 3S5

Poplar Council of Canada
Office of the Secretariat
c/o Northern Forestry Centre
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Edmonton, Alberta
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Navratil, S.; Chapman, P.B., editors. 1991. *Aspen management for the 21st century*. Proceedings of a symposium held November 20-21, 1990, Edmonton, Alberta. For. Can., Northwest Reg., North. For. Cent. and Poplar Counc. Can., Edmonton, Alberta.

ABSTRACT

The Aspen Management for the 21st Century symposium was held in conjunction with the 12th annual meeting of the Poplar Council of Canada in Edmonton, Alberta. Twenty-one invited papers were presented in four topical sessions: aspen management—filling the knowledge gaps; aspen management and harvesting; wildlife, environment and aspen management; and sustainability and intensive management of the aspen resource. Emphasis was put on integration of management, harvesting, and non-timber uses. Proceedings contain all invited papers and abstracts of the concurrent poster session.

RESUME

Le symposium sur la gestion du peuplier faux-tremble à l'aube du XXI^{e} siècle (*Aspen Management for the 21st Century Symposium*) a eu lieu conjointement avec la XII^{e} réunion annuelle du Conseil canadien du peuplier (*Poplar Council of Canada*) à Edmonton, en Alberta. Au total, 21 communications sollicitées ont été présentées dans les quatre séances thématiques: acquisition des connaissances manquantes en matière de gestion du peuplier faux-tremble; gestion et récolte du peuplier faux-tremble; faune et flore, environnement et gestion du peuplier faux-tremble; et soutenabilité et gestion intensive de cette ressource. L'accent a été mis sur l'intégration de la gestion, de la récolte et des utilisations autres que l'exploitation forestière. Les présents actes comprennent toutes les communications sollicitées et les résumés des affiches exposées durant le symposium.

FOREWORD

The 1990 Aspen Management Symposium offered western Canadians the opportunity to discuss a variety of resource management topics dealing with aspen and poplar.

Presented papers covered the subjects of aspen regeneration, inventory, growth and yield, harvesting, effects of utilization on site productivity, mixedwood management, rehabilitating decadent stands, wildlife management, public concerns in aspen management, genetic improvement, thinning, woodlot potential, aspen and climate change, and the sustainability of the aspen resource.

A concurrent poster session included topics such as fire prediction, integration of habitat and timber management, decision support system development, preharvest manual control of suckering, ecosystem modeling, classification of decay and stain, nonforested productive land classification, economics of harvesting overmature aspen, stand development, site classification, and biological effects of fire.

The interest and enthusiasm of symposium participants demonstrated the importance and timeliness of the material and prompted us to make the proceedings available in the shortest time possible. We have achieved this through the cooperation of the speakers.

The papers presented here are published as they were submitted with only technical editing and standardization of style. The opinions of the authors do not necessarily reflect the views of the Poplar Council of Canada or of the sponsors of this symposium.

We would like to acknowledge the support of the Northern Forestry Centre of Forestry Canada in providing the cover, typing, expert advice on publication, printing, and for allowing the time for our work.

A great many individuals contributed to the overall success of the meeting and publication of this proceedings. They are: C. Abma, D. Allan, R. Andries, I. Bella, L. Brace, C. Brokop, F. Dendwick, R. Hayward, C. Henderson, J. Kitz, L. Johnson, B. Laishley, D. Lee, D. MacIsaac, J. Mrklas, R. Newstead, L. Ross, A. Ruff, J. Samoil, E. Schiewe, J. Simunkovic, J. Sloan, T. Szabo, J. Van Dyk, R. Waldron, and A. Yasinski. Technical editing was done by B. Boughton.

Stan Navratil
Paul Chapman
Editors

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NOTE

The views in the articles are those of the authors and do not necessarily imply endorsement by symposium sponsors.

The exclusion of certain manufactured products does not necessarily imply disapproval nor does the mention of other products necessarily imply endorsement by the Poplar Council of Canada, Forestry Canada, or the sponsors of the symposium.

WELCOME AND INTRODUCTORY REMARKS

S. Navratil
Forestry Canada
Edmonton, Alberta

Good morning ladies and gentlemen, and welcome to the aspen management symposium of 1990.

About a year ago we began to plan a small aspen management workshop in conjunction with the 1990 annual meeting of the Poplar Council of Canada, to be held in Edmonton, Alberta. This concept was welcomed by the management of the Northern Forestry Centre, Forestry Canada, who offered to sponsor it to the level of symposium. When we approached Alberta Forestry, Lands and Wildlife with the idea of a symposium they also endorsed the topic and size. Due to these decisions and to your response to our first announcement we upgraded the scale of the meeting to symposium level in midstream. Today we have over 200 people in the audience, and that alone attests well to the timeliness of the topic.

This symposium is jointly sponsored by the Poplar Council of Canada; Northern Forestry Centre, Forestry Canada; and Alberta Forestry, Lands and Wildlife. Additional financial support from the Forest Industry Development Division of Alberta Forestry, Lands and Wildlife, Daishowa Canada Corporation, and Wajax Industries Ltd. is also gratefully acknowledged.

All the presentations at this meeting are invited papers, and we are indebted to the speakers for accepting their nominations. We have been fortunate to bring together a group of renowned specialists from several fields, including forest management, wildlife, environment, and public interests, from across Canada and the United States.

Our intent in selecting the topics and speakers was to present to you a symposium where the management of the aspen resource for fiber and for other uses and public concerns would be discussed together at the practical level. It is not a symposium for researchers but for practicing forest and land managers. To my knowledge it is the first of its kind in Canada. For the same reason the moderators of the sessions are experienced forest managers whom I am confident will provide a climate conducive to productive exchanges.

I will now reverse the order a bit; instead of thanking the organizing committees at the end as is customary, I would appreciate it if you would note the page in your program listing some of the people who helped in various functions. They all have worked hard, making my day on many occasions. We all hope that the preparations we have made for the next two days will be fruitful and pleasant for you.

Again, my personal warm welcome to all of you.

OPENING REMARKS

A.D. Kiil
Regional Director General
Forestry Canada - Northwest Region
Edmonton, Alberta

Good morning! It is both a privilege and a distinct pleasure for me to welcome you to this symposium, Aspen Management for the 21st Century. Forestry Canada, in collaboration with Alberta Forestry, Lands and Wildlife and the Poplar Council of Canada, is pleased to sponsor this important and timely event.

I would like to recognize Stan Navratil's leadership role in organizing an outstanding program that has attracted many prominent speakers. It follows that the individual presentations will serve as excellent barometers of current knowledge, knowledge gaps, and future needs pertaining to aspen management.

The theme of this symposium is forward looking and comprensive in the sense that it focuses on timber as well as nontimber attributes of the forest. This recognition of the multiple values and uses of the forest is consistent with the principles embodied in the term "sustainable development" and will therefore contribute to our selection and delivery of research programs that are responsive to expectations of our clients.

In recent years, it has become fashionable to be involved in strategic planning, i.e., setting a course for the future. This emphasis is rooted in the rapid pace of change all around us. Prevailing perceptions about forests and forestry, such as high public awareness of forestry, concerns about the health of the forest, a need to recognize the nonfiber values of the forest ecosystem, and fears about running out of wood, are all indicative of change. The forest sector itself is changing. Nowhere is this more evident than in the prairie provinces, especially Alberta, where significant new investment since the mid-1980s has more than doubled production capacity.

Given the above context, it is therefore not surprising that Forestry Canada, along with other forest sector players, is involved in strategic planning by analyzing the rapidly changing working environment and in determining strategic directions.

At the national level, the end product of this effort is a strategic plan entitled *Forestry Canada–preparing for the future*, which provides a focus for future activities in four strategic areas, namely national leadership, forest sector development, forest environmental quality, and science and technology. Guided by the principle of sustainable development, we have identified, and are in the process of implementing, 24 strategic initiatives, ranging from a comprehensive report to Parliament, to negotiation of new federal-provincial forestry agreements, to the establishment of a national forest resource data program.

A similar strategic planning exercise has been completed at the regional level and documented in *Toward the 21st century forest*. This plan, based on a thorough assessment of ongoing activities in relation to recent forest sector developments and trends, outlines key assumptions, operating principles, and core values, and identifies our new directions for forest research and development in the prairie provinces and the Northwest Territories.

We concluded that about 75% of the ongoing programs and activities and their resources would continue to address well-known issues such as regional development, the wood supply, and losses from man-caused and natural disturbances such as fire and pests.

Kiil, A.D. 1991. Opening remarks. *In* S. Navratil and P.B. Chapman, editors. Aspen management for the 21st century. Proceedings of a symposium held November 20-21, 1990, Edmonton, Alberta. For. Can., Northwest Reg., North. For. Cent. and Poplar Counc. Can., Edmonton, Alberta.

The remaining 25% of the available resources over the next 5 years will be assigned to implement five new thrusts concerned with decision support systems (DSS), climate change, application of research products, i.e., technology transfer, multiple-use resource management, and aspen management.

Before closing, I would like to talk briefly about four of these new program thrusts and to outline how they relate to the theme of this symposium. First, we intend to develop research programs to assist in integrating and applying forest management activities in support of the sustainable development of nontimber forest resources and values. Expected achievements include participation in and support of integrated forestry-wildlife-habitat studies, and provision of guidelines on the economic and social aspects of multiple-use for tourism, recreation, and forestry.

Secondly, operational decision support systems will be developed for integrated management of boreal mixedwood and aspen forests. The catalysts for this new thrust are the resources of projects in mixedwood silviculture, site classification, stand productivity, and soils research, with linkages to fire and pest management systems.

Thirdly, we have already established a Technology Development Unit (TDU) to develop and transfer technology to clients. Unit staff will maintain close contact with researchers and practitioners throughout the region and elsewhere and will focus on application of innovative procedures and technology.

Fourthly, we are committed to the development of an Aspen Innovation Centre to provide leadership and coordination of applied research and technology transfer capability aimed at improved aspen management and utilization. We intend to establish an outward-looking approach for the dissemination of information on the aspen resource and its management. A major new multi-agency research program will be initiated to develop disease resistance in regional species through biotechnology research.

I am also very pleased to announce the recent relocation of the Poplar Council of Canada Secretariat to the Northern Forestry Centre. The council has a strong record of achievement in promoting enlightened poplar management and utilization in Canada, and we are extremely pleased to accommodate the council in western Canada. I expect that the presence of the council's secretariat here will further enhance its leadership and coordination role, especially in support of emerging needs for aspen management.

These are but a few of the new directions and initiatives established or being pursued by Forestry Canada at national and regional levels. With these initiatives, we are positioning ourselves to fulfil the departmental mandate and to provide the best possible service to various forest sector clients through high-quality research and regional development activities.

The decade of the 1990s promises to be full of opportunities, and I see this symposium as an important step in firming up our research thrusts so that the forest sector, as the primary beneficiary of this effort, will be in a strong position to meet the challenges of the 21st century.

SESSION I

ASPEN MANAGEMENT —

FILLING THE KNOWLEDGE GAPS

Moderator: M. Little
Saskatchewan Parks and Renewable Resources
Prince Albert, Saskatchewan

LEARNING FROM THE PAST FOR THE FUTURE[1]

INTRODUCTION

After 35 years in forestry, I believe I can wax eloquently about Forestry Canada's research and development (R&D) contributions to aspen management in ecology, biology, silviculture, insects and diseases, ecological site classification, stand tending, and mixedwood management. However, I will resist the urge to pontificate on past glories. All of our R&D findings are duly recorded in the literature and have been presented at both field-orientated workshops and at formal symposiums. In my talk today I will attempt to reflect on the old axiom "Those who do not learn from the past are condemned to repeat it." More specifically I would like to address the failure of researchers to impact on forest management and the failure of the practicing forester to learn from forest researchers.

I propose to deal specifically with three current forestry myths: 1) we know nothing about aspen management; 2) site classification and PHSPs are the new kids on the block; and 3) we have no R&D experience in mixedwood harvesting systems.

MYTH 1: WE KNOW NOTHING ABOUT ASPEN MANAGEMENT

This thesis may sit well with 1) the new kids on the block; 2) Johnnies-come-lately; or 3) researchers starting their careers. Depending on how well *you* have kept up with the science you might say 1) it's true; 2) it's not true; or 3) bull roar.

When others say, "*We* don't know enough about aspen management," you can safely say, "*You* don't know much about aspen management." I would argue that collectively, researchers and practicing foresters know enough to improve current management practices. So why do some people call for more R&D? I suggest the following somewhat facetiously:

1. Researchers call for more R&D in aspen management because a) it gives them the opportunity to reinvent the wheel; b) they can continue to operate in a vacuum; or c) both of the above.

2. Practicing foresters call for more R&D in aspen management in order to a) avoid dealing with researchers in solving practical problems; b) buy time and/or save a few dollars and delay implementation of improved forest management practices; or c) both of the above. For both 1) and 2) the answer is c.

Let's look at the record (Table 1). Twenty-five major publications on ecology, management, and use of aspen have been written since 1955, and every forester responsible for aspen or aspen-white spruce management should have copies in their office or personal library!

Peterson, in his soon-to-be-released publication on ecology, management, and the use of aspen and balsam poplar in the prairie provinces of Canada, covers over 60 technical subjects based on 2000 references relating directly to Manitoba, Saskatchewan, Alberta, and northeast British Columbia. In truth we know more about aspen than we do about white spruce!

I don't believe we need more R&D! What we need is more discussion between researcher and practitioner. It is my opinion that *task forcing* is a more productive technique for resolving problems and improving forest management. Task forcing requires a clear definition of a problem and bringing together the expertise to resolve it. In my opinion sufficient information and experience is available to resolve most if not all aspen management problems. It is not research we need but the will and the commitment to sustainable development.

[1] Excerpts from the paper entitled "Learning from the past for the future: Musings of an old fart" presented by R.M. Waldron at the Aspen Management for the 21st Century Symposium held November 20-21, 1990, Edmonton, Alberta. For. Can., Northwest Reg., North. For. Cent. and Poplar Counc. Can., Edmonton, Alberta.

Table 1. Major publications written on the ecology, management, and use of trembling aspen, 1955-91

Date	Title	Authors
1955	A review of literature relating to quaking aspen	Heinselman and Zasada
1961	Ecology of the aspen parkland	Bird
1962	Silvical characteristics of quaking aspen	Strothman and Zasada
1963	Aspens: Phoenix trees of the Great Lakes Region	Graham et al.
1967	Trembling aspen in Manitoba	Manitoba Section, CIF Waldron
1968	Growth and utilization of poplars in Canada	Maini and Cayford
1972	Aspen symposium proceedings (Duluth)	USDA Forest Service
1974	Present and future uses of Canadian poplars in fibre and wood products	Keays et al.
1974	Poplar utilization symposium	Neilson and McBride
1975	Quaking aspen: Silvics and management in the Lake States	Brinkman and Roe
1976	Utilization and marketing as tools for aspen management in the Rocky Mountains	USDA Forest Service
1977	Manager's handbook for aspen in the north central States	Perala
1980	Utilization of western hardwoods	McIntosh and Carroll
1981	Boreal mixedwood symposium—Ontario	Whitney and McClain
1983	Silvicultural systems for the major forest types of the United States	Burns
1985	Utilization of hardwoods in northern Alberta	Woodbridge, Reed and Associates Ltd.
1985	Aspen: Ecology and management in the western United States	DeByle and Winokur
1987	Aspen quality workshop	Canadian Forestry Service/Alberta Forest Service
1987	Proceedings of the workshop on aspen pulp, paper and chemicals	Wong and Szabo
1988	Utilization and marketing opportunities for Alberta aspen	Wengert
1988	Management and utilization of northern mixedwoods	Samoil
1988	A silvicultural guide for the poplar working group in Ontario	Davison et al.
1988	Management and utilization of Alberta poplars	Poplar Council of Canada
1989	Aspen symposium '89 proceedings (Duluth)	USDA Forest Service
1991	Ecology, management, and use of aspen and balsam poplar in the prairie provinces, Canada	Peterson and Peterson

It has been said that we are now in the information age, and information is power. If the practicing forester has not kept up-to-date on research findings on aspen management, then researchers by default have the power. Expert witnesses is what current court cases, panel reviews, and Environmental Impact Assessments (EIAs) are all about. At the 1989 annual Alberta Biologists' meeting the executive director of Greenpeace, who is a lawyer, suggested that in order to improve forest management and reduce environmental impacts we need more scientists in politics. How do you like them microscopes!!

What is missing for aspen management is a framework in which researchers and practicing foresters can pigeonhole their knowledge and experience and from which they can draw the information to develop PHSPs (PreHarvest Silviculture Prescriptions). Which leads me to Myth #2.

MYTH 2: SITE CLASSIFICATION AND PHSPs ARE THE NEW KIDS ON THE BLOCK

This is also untrue. Note from Table 2 that site classification 1) began on the prairies as early as 1931; 2) has covered the three provinces; 3) has resulted in the development of not one but many systems and associated clones; and 4) has involved an impressive list of well known regional foresters and researchers. A recent survey showed most practicing foresters in the region do not use any of the systems devised—even though some are mapped! So why has no fully operational site classification been devised to date? Because 1) scientists are looking for the ideal; it's the reinventing of the wheel syndrome; 2) practicing foresters felt they could manage on the basis of cover type, which was probably true in the 1950s and '60s; 3) the supposed lack of correlation between growth and yield and ecological site units resulted in site not being

Table 2. Site classification in the prairie provinces, 1931-89

Date	Location	Basis	Principal investigators
1931	Riding Mountain, Manitoba	Vegetation	Halliday
1935-present	Agricultural lands	Soils survey[1]	Agriculture Canada
1946	Kananaskis Forest Experiment Station, Alberta	Soils survey	Crossley
1951-62	Riding Mountain, Manitoba	Hills	Rowe
1953-57	B18a, Alberta	Soils	Quaite/Duffy
1957-?	Manitoba and Saskatchewan	Hills	Rowe
1960-65	Sandilands Forest Reserve, Manitoba	Braun-Blanquet	Mueller-Dombois
1965-75	Canada productive forest lands	Forest landscapes	Canada Land Inventory, Environment Canada
Circa 1968	Northwest Pulp and Power, Alberta	Landforms	Gimbarzevsky
1969	Canada forestlands	Biophysical	Lacate
1976	Saskatchewan	Soils/vegetation	Kabzems
1974-84	National parks, Alberta and British Columbia	Biophysical	Holland et al.
1977-86	West-central Alberta	Biogeoclimatic	Corns/Annas
1986-present	Southwestern Alberta	Biogeoclimatic	Sivak
1986-89	Duck Mountain, Sandilands Forest Reserve, Manitoba	Biophysical	Wells/Pedocan

[1]Forestry interpretations: Duffy 1963; Cayford/Jameson 1964; Zoltai 1965.

adequately built into provincial inventory systems. It is agreed that site index (SI) has proven to be a useful surrogate for site classification for inventory and cover-type management over the years. But the lack of ecological definition of harvested and other silviculturally treated areas has cost the silviculturist dearly and has significantly set back the integrated forest resource management of aspen and mixedwood forests for their many uses. The lack of an operational ecological site classification system has also significantly reduced the value of mission-oriented R&D over the past 30 years and retarded the development of successful forest management practices on the prairies. Cover-type management is no longer an acceptable substitute for ecosystem management. Sustainable development relies on ecosystem management.

It should be noted that in the 1970s provinces opted to hire staff to get into intensive forest management practices like tree improvement and insects and diseases, both of which—like silviculture—require an ecological site classification system to achieve the benefits of operational programs. It appears now that some prairie provinces are ready to adopt ecological site classification—a 30-year gestation period. Even elephants have only a 2-year gestation period—and we thought dinosaurs were dumb! Tommy Thomson[2] had it right. We should have fired all Forestry Canada researchers in the 1960s and hired practical ecological site classification experts to map our forest lands. British Columbia has done it, but we continue to drag our feet.

In the old days, PHSPs were equivalent to the site-specific prescriptions developed by Forestry Canada researchers for a number of harvesting, regeneration, and stand tending opportunities, but they had restricted application because of the lack of a site classification system that would permit interpretation and extrapolation to other sites. Forestry Canada in recent years has been criticized for developing these generic silviculture prescriptions; some senior forest managers apparently preferred the mensurational approach (SI) to forest management. I believe that silviculture prescriptions as well as inventory and mensuration techniques and measures based on natural ecosystems will serve both forest managers and silviculturalists better in the future.

If site classification and PHSPs are not the new kids on the block, what is! Decision support systems (DSS) are. They are interactive computer-based systems designed to assist practicing foresters make management decisions at the stand, forest, and landscape levels. When fully developed, DSS will support decisions made at the operational and planning levels. They permit the integration of knowledge and experience and will offer a rational basis for forest management decisions. Fire protection has their IFMIS, Integrated *Fire* Management Information System. Silviculturalists should have their Integrated *Forest* Management Information System.

Do you remember in 1st-year university when our deans told us "forest management is a combination of science (researcher provides) and art (field forester provides)?" Both researchers and foresters have been handicapped by the lack of an operational ecological site classification and the slavish adherence to restrictive provincial ground rules.

The technology of DSS involves domain experts and artificial intelligence. Field foresters in the audience are the domain experts. I will leave it to you to decide who is providing the "artificial intelligence!" Others will speak to this subject in more detail.

MYTH 3: WE HAVE NO R&D EXPERIENCE IN MIXEDWOOD HARVESTING SYSTEMS

The history of R&D harvesting in mixedwood stands is shown in Table 3. Until 1955, diameter limit cutting was in vogue; the initial diameter limit was 16 inches but was reduced to 8 inches over the years. Regeneration of white spruce in both research and operational harvested areas was a failure (principally because no site preparation was undertaken). In 1955 the three prairie provinces asked Forestry Canada to undertake more classical types of harvesting

[2]C.C. (Tom) Thomson, former Regional Director, Canada Department of Forestry and Rural Development, Manitoba-Saskatchewan Region, Winnipeg, Manitoba.

Table 3. Research and development in mixedwood[1] harvesting systems in the prairie provinces, 1924-89

Date	System[2]	Location
1924	(A) (C) (D)	Pasquia Hills, Saskatchewan
1937	(C) (D)	Duck Mountain, Manitoba
1951	(B) (C) (D) (E)	Smith, Alberta
1953	(D)	Smith, Alberta
1953-55	(D)	Riding Mountain, Manitoba
1958	(D)	Smith, Alberta
1960-65	(A)	Manitoba and Saskatchewan
1962	(D)	Manitoba and Saskatchewan
1964-67	(D)	Riding Mountain, Manitoba
1965	(B)	Hudson Bay, Saskatchewan
1972	(F)	Porcupine Mountain, Saskatchewan
1989	(F)	Western Alberta

Principle investigators: Lees/Jarvis/Waldron/Brace.

[1]Aspen and white spruce.
[2]A) strip; B) clear-cut; C) seed tree; D) shelterwood by basal area/volume; E) diameter limit (after 1950); F) understory protection.

systems. But by 1960, operational clear-cutting of white spruce in mixedwood stands was in practice. Forestry Canada continued to establish and report on cutting experiments through the 1960s in Manitoba, Saskatchewan, and Alberta, and large scale (full section) shelterwood logging and scarification were carried out in the Riding Mountain Forest Experimental Area. Following the demise of the Winnipeg and Calgary offices in 1970 the experiments were dropped. In 1972 Froning undertook understory protection harvesting in aspen stands. These experiments were repeated in Alberta in the late 1980s by a consortium of foresters led by Lorne Brace. This harvesting system shows great promise. With renewed interest in alternatives to clear-cutting in mixedwood stands, it is imperative that these old experiments be revisited and that their potential for use in today's forest management be assessed.

In the event that the audience (or reader) believes that it is equally true that we know nothing about thinning aspen or growing mixedwoods I have provided appropriate tables (Tables 4 and 5) outlining significant R&D efforts in these areas.

Table 4. Research and development in aspen thinning in the prairie provinces, 1926-64

Date	Location
1926	Riding Mountain, Manitoba
1926	Duck Mountain, Manitoba
1937	Duck Mountain, Manitoba
1937	Kananaskis, Alberta
1948	Turtle Mountain, Manitoba
1950	Riding Mountain, Manitoba
1951	Porcupine Mountain, Manitoba
1964	Porcupine Mountain, Manitoba

Principle investigators: Steneker/Bella.

Table 5. Research and development in growing mixedwood[1] stands in the prairie provinces, 1924-63

Date	Research activity[2]	Location
1924	(A)	Big River, Saskatchewan
1930	(B)	Porcupine Mountain, Saskatchewan
1936	(A)	Duck Mountain, Manitoba
1951	(A)	Fawcett Lake, Alberta
1951-54	(A)	Manitoba and Saskatchewan
1961	(A)	Western Saskatchewan
1962	(B)	West-central Alberta
1962-68	(B)	Manitoba
1963	(A)	McKay, Alberta
1963	(C)	Manitoba and Saskatchewan

Principle investigators: Cayford/Steneker/Jarvis/Waldron/Lees/Yang.

[1]Aspen and white spruce.
[2](A) release and improvement cuttings; (B) under planting aspen; (C) competition modeling.

I realize that I have offered my comments on the basis of 20-20 hindsight. It appears to me that the failure of researchers and practicing foresters to get ecological site classification operational in the 1960s or 1970s has resulted in a significant set back in ecosystems management. Similarly not following through on the mixedwood harvesting systems experiments of the 1950s and 1960s constitutes another missed opportunity. Researchers can, however, be applauded for effectively building up our knowledge base for aspen management in advance of its commercial utilization. Looking back it is apparent that the leisurely R&D days I experienced in the '50s, '60s, and '70s did not serve us well in the 1980s, nor will they in the 1990s. Time available for resolving today's problems in the areas of climate change, carbon balance, environment protection, and mixedwood ecosystem management is limited. Long-term experimentation is not possible. We need to undertake more task forcing—using our libraries and our heads to arrive at meaningful conclusions and to change the way we manage the forest. The development of Decision Support Systems (DSS) for use in integrated resource management will not be available for some time. While we need to build on our past R&D efforts, it is imperative that we restructure the way we do R&D; we need to develop more effective partnerships, and we need to involve other groups interested in the integrated management of our forest resources. I believe that these types of changes are currently being made. I must admit that as I enter the hallowed halls of [retirement] I feel a certain sense of senatorial smugness. A smugness that comes at the end of a career when you feel you can live with your success and explain away the failures. For those who suffer from papal infallibility syndrome you may feel that I've been barking up the wrong tree.

REGENERATION CHALLENGES

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ABSTRACT

Aspen regeneration after harvesting deciduous stands in Alberta and Saskatchewan, over the past 10 years and 30 years respectively, has produced successful sucker stands on many sites. There are, however, some areas with unsatisfactory stocking. The principles of aspen silvics, regeneration silviculture, biological, site and harvesting constraints on aspen suckering and seedling establishment are examined in the framework of regeneration targets and management strategies.

INTRODUCTION

Aspen has gained critical commercial significance in western Canada. The gap between annual allowable cut and harvest is narrowing very quickly in all three prairie provinces (Navratil et al. 1990). In Alberta, the utilization of aspen may reach 6 million m^3 in 1991 and 8.5 million m^3 in 1993. Conservatively estimated, the 1991 level of aspen utilization in Alberta can be projected to about 50 000 ha of cutover area to be regenerated.

Practical experience shows that aspen is easy to regenerate naturally; it readily forms root suckers and produces abundant seed crops. Yet foresters have observed instances where aspen regeneration after harvesting is unsatisfactory. Forest managers in western Canada have been quick to recognize that successful aspen regeneration may not be as simple as expected, and that " .. *perhaps desirable hardwood regeneration is not free after all*" (Smith 1989).

Navratil, S. 1991. Regeneration challenges. *In* S. Navratil and P.B. Chapman, editors. Aspen management for the 21st century. Proceedings of a symposium held November 20-21, 1990, Edmonton, Alberta. For. Can., Northwest Reg., North. For. Cent. and Poplar Counc. Can., Edmonton, Alberta.

The questions asked by foresters and the public alike are, "How difficult is it to achieve acceptable levels of aspen regeneration?" and "Will the large scale of future aspen regeneration requirements pose special problems?"

The objective of my talk is to highlight facts and questions about aspen regeneration, to reveal areas requiring attention, and to give my view of what is required to meet the regeneration challenge.

WHAT AFFECTS ASPEN REGENERATION

In practice, many factors in combination may explain differences in the density and quality of aspen regeneration. In the extreme, an undesirable combination of regeneration silvics, site, and harvesting practices can limit or eliminate aspen regeneration. On the other hand, the application of sound regeneration principles and harvesting practices can maximize aspen regeneration and growth, and may allow aspen regeneration densities to reach the most desirable levels.

When developing a prescription for aspen sucker regeneration it is important to remember that aspen suckering is affected by many factors, and none of these should be considered in isolation. For example, the effect of summer versus winter harvesting on suckering is also influenced by the latitude and associated soil temperature, thickness of duff layer, site moisture regime, soil texture, shrub and herbaceous competition, and harvesting methods.

I believe that the key to successful aspen regeneration lies in the interaction of aspen silvics, site, and harvesting practices, and I will emphasize these in my presentation.

REGENERATION SILVICS

Regeneration by Root Suckering

The processes controlling aspen reproduction by root suckering are well understood and well described (DeByle and Winokur 1985; Doucet 1989; Navratil and Bella 1989). They include three major factors: apical dominance, soil temperature, and light available to emerging suckers.

Apical dominance is expressed by the ratio of auxins and cytokinins in the roots. Auxins formed in the aboveground parts of aspen suppress suckering. Cytokinins formed in the roots promote suckering. Disturbance of the ratio of these two hormones, for example, when the flow of auxins from the aboveground parts to the roots is interrupted, by cutting the tree or wounding the roots, triggers sucker development.

Soil temperature is considered to be the primary factor controlling suckering when apical dominance is removed. Higher temperatures degrade auxins and increase production of cytokinins in the root tissues, thus altering apical dominance. Suckering is inhibited when soil temperature is less than 15°C (Maini 1967), and soil temperature must reach 20°C for maximum sucker production (Steneker 1976). Low soil temperatures may be the reason for poor suckering in northern regions and on sites insulated with thick duff or vegetation layers. However, interclonal and regional differences in the suckering responses to temperature have been observed (Maini 1967; Zasada and Schier 1973). Even when apical dominance is not removed, increases in soil temperature stimulate suckering, for example, in partial cuts where aspen is left standing. This accounts for the gradual invasion of areas adjacent to aspen stands.

Light is not required for sucker initiation; however, reduced light levels due to vegetative competition or residual canopy can slow the growth of emerging suckers and lead to sucker mortality.

Regeneration by Seed

A mature aspen tree produces up to 1.5 million seeds per crop. These seeds are dispersed by wind and can travel hundreds of kilometres (Maini 1967). Despite abundant seed crops and effective seed dispersal it was believed until recently that seed bed conditions favorable for seedling establishment were rarely met.

Recent research at the Northern Forestry Centre (NoFC) and elsewhere documents the relative frequency of aspen seedling establishment. In northern areas like northeastern British Columbia and Alaska it has been suggested that seed regeneration may be more important than sucker regeneration because of cold soil conditions that reduce suckering capacity (Zasada et al. 1977).

In the foothills of Alberta pine cut blocks with a favorable moisture regime had aspen seedlings at densities of 1500 to 16 000 per hectare (Fig. 1).

Seedling reproduction enables aspen to invade new areas after logging and particularly after site preparation. Owing to the critical conditions and relatively narrow window required for aspen seedling establishment—exposed mineral soil with adequate soil moisture and the lack of competing vegetation for a considerable period—aspen reproduction by seed cannot be confidently predicted and relied on.

IMPACT OF HARVESTING ON ASPEN SUCKERING AND REGENERATION

Clearcutting and mechanized harvesting operations can create optimum conditions for aspen regeneration by suckering. Conversely, harvesting can severely affect aspen regeneration, depending on a combination of timing and type of harvesting and the site and soil conditions.

Residual Canopy

Complete clear-cutting without leaving any residual canopy leads to the best sucker development. The total removal of shade enhances soil warm-up and light availability and consequently promotes sucker initiation and sucker growth. Residual canopy interferes with these processes.

There are clear relationships between the amount of residual canopy and suckering

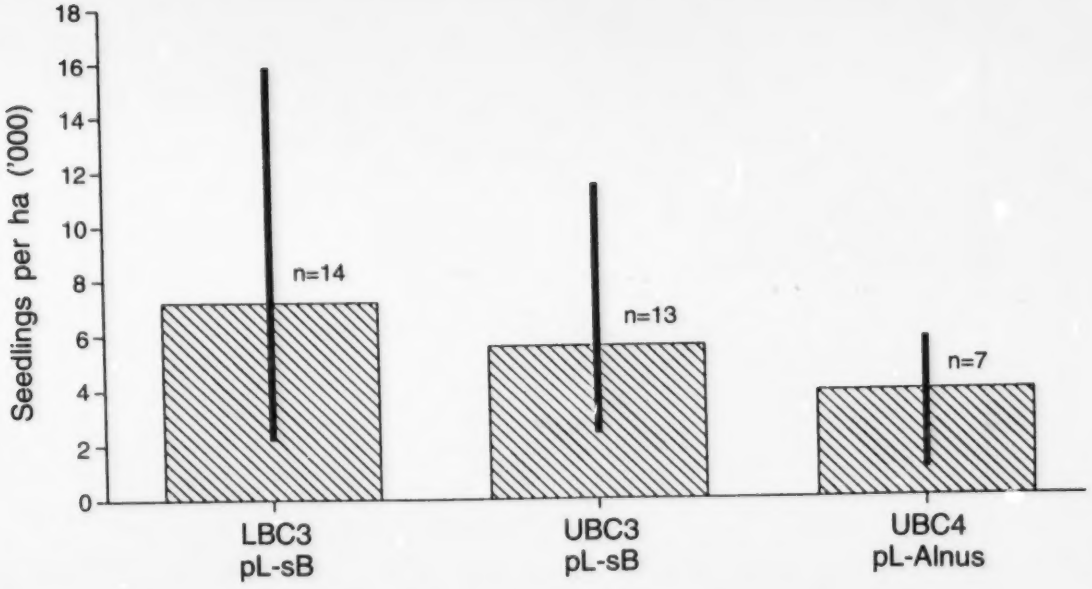

Figure 1. Aspen density of seed origin in cut blocks at 7-20 years after harvest in pine cover types in the foothills of Alberta. Bars indicate the ranges (from Navratil et al. 1990). Ecosystem associations after Corns and Annas (1986). LBC 3 Pl-Sb and UBC 3 Pl-Sb = lodgepole pine-black spruce/Labrador tea/feather moss; UBC 4 Pl/*Alnus* = lodgepole pine/alder.

density and growth. Aspen management guides in the United States recommend a maximum residual overstory of 2.3 m^2/ha of the basal area (Perala 1977; DeByle and Winokur 1985). A basal area of no more than 4 m^2/ha is often enough to eliminate many suckers and adversely affect their growth (cited in Doucet 1989).

In northern Wisconsin, on heavily shaded areas with 9.2 m^2/ha of residual basal area, sucker density was reduced almost 20 times, from 6720 to 345 suckers per hectare. The suckers grew only to one-third the height of those on clearcuts (Stoeckeler and Macon 1956). The multiple effects of a partial cut and increased competition by hazel and alder on the quality of aspen regeneration, including reduced stocking and reduced growth, were observed by Doucet (1989).

In a study in Manitoba, Waldron (1963) assessed the effect of residual basal area of white spruce and aspen on aspen stocking 5 years after cutting (Fig. 2). The inverse relationship and levels of residual basal area required for adequate stocking observed are comparable to the recommended maximum levels quoted above.

The following example illustrates these relationships. If operating ground rules for aspen harvesting require that a minimum of 60% of the tree canopy must be removed to promote aspen regeneration on a medium site (basal area 34 m^2/ha at 80 years (Plonski 1974)) and the operator complies and removes 70% of the canopy, the resulting basal area will be about 11 m^2/ha. The value corresponding to 11 m^2 of basal area in Figure 2 shows that stocking levels higher than 50% may be difficult to achieve by 5 years after cutting with this level of residual canopy.

It should be noted that the above example extrapolates from different data sources. The

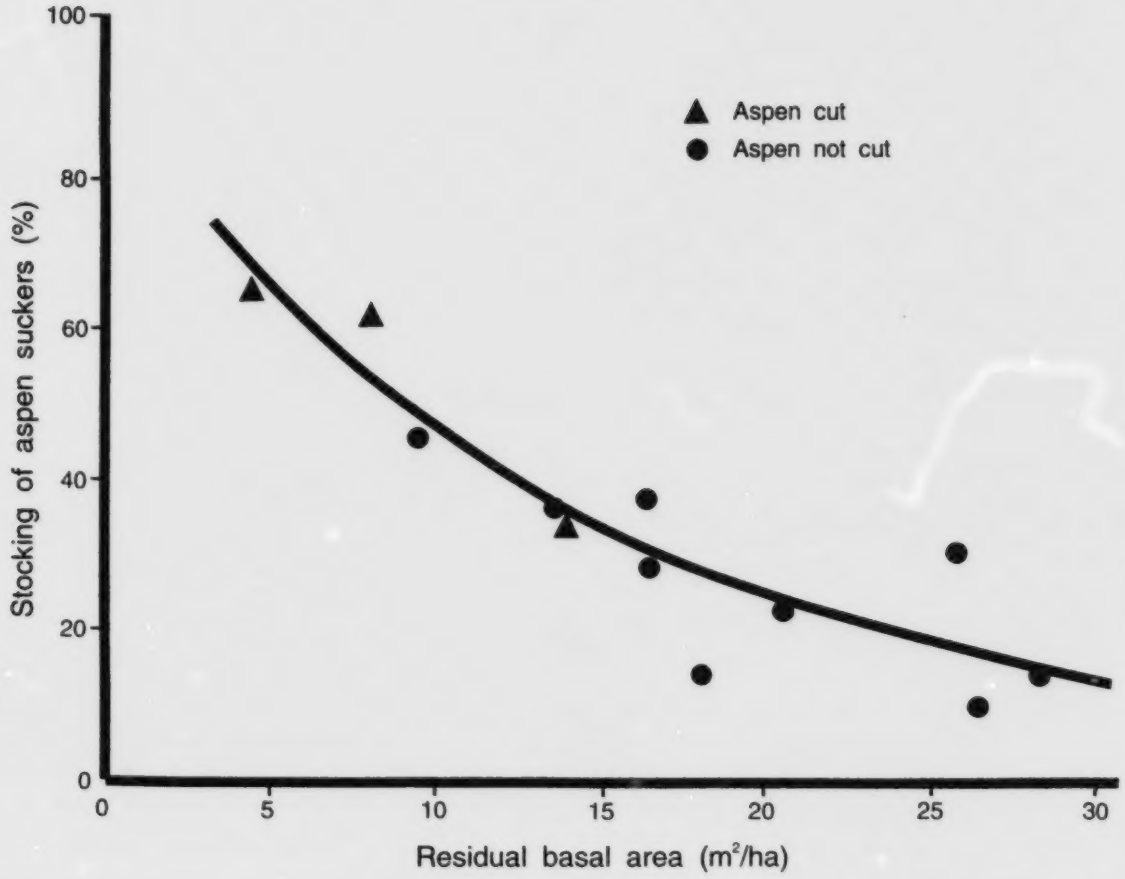

Figure 2. Relationship between stocking of trembling aspen suckers and residual basal area (white spruce and aspen) 5 years after cutting. 200 plots per plotted point (from Waldron 1963).

relationships may vary with regional differences and the composition of the residual canopy. Aspen residuals, for example, exert a greater effect on suckering than associated balsam poplar because of their apical dominance and greater shading.

Season of Harvest and Soil Disturbance

Summer harvesting has the potential to enhance aspen regeneration. It reduces vegetation cover and scarifies thick duff layers. As a result, the soil becomes warm enough for good suckering. Summer harvesting also assists emerging suckers by removing herbaceous and shrub competition.

The increased soil temperatures associated with summer harvesting may be critical in the northern boreal forest. Poor suckering observed in Alaska and northeastern British Columbia is believed to be due to the inhibiting effect of low soil temperature (Zasada et al. 1977; Peterson et al. 1989). A thick duff layer and dense shrubs and grass can significantly delay soil warm-up in the spring and thus hinder aspen regeneration. Hogg and Lieffers (1990) found a 1-month delay in soil warming above 0°C in *Calamagrostis* cover as compared to a clear area, and the maximum temperature was 12°C in soil under grass, which appears to be too cold for suckering. Light scarification and the partial removal of herbaceous cover and shrubs by summer harvesting was suggested to be the major reason

for the higher sucker density observed on summer cuts in a trial in Saskatchewan (Bella 1986).

On the other hand, summer harvesting may reduce the number and vigor of suckers. The lower carbohydrate content in roots in the summer reduces suckering ability. Suckers initiated in the late summer are also more frequently damaged by early frost.

Most importantly, summer harvesting increases the risk of soil and root disturbance that can reduce suckering on sensitive sites. In Alberta's Edson Forest, lower aspen stocking levels were found more frequently on summer cuts than on winter cuts (Fig. 3). Similarly, in a survey of poorly regenerated stands in Minnesota (Bates et al. 1990), most of poor regeneration was associated with summer harvest, particularly early summer harvest. Substantial site disturbance by skid trails and landings, including soil compaction and interrupted drainage on hardwood cutovers, has been implicated in understocking and poor growth of aspen in Alberta (Expert panel on forest management in Alberta 1990).

Soil Compaction

Soil compaction is caused by a pressure that exceeds soil strength. It results in the rearrangement of soil particles and a decrease in pore volume. Root growth and proliferation can be impaired from reduced soil aeration and increased mechanical impedance (Standish et al. 1988). Soil compaction could affect several processes of aspen regeneration: sucker initiation on the roots, rate of sucker emergence and growth, development of new sucker roots, soil-seed contact, seed germination, and seedling

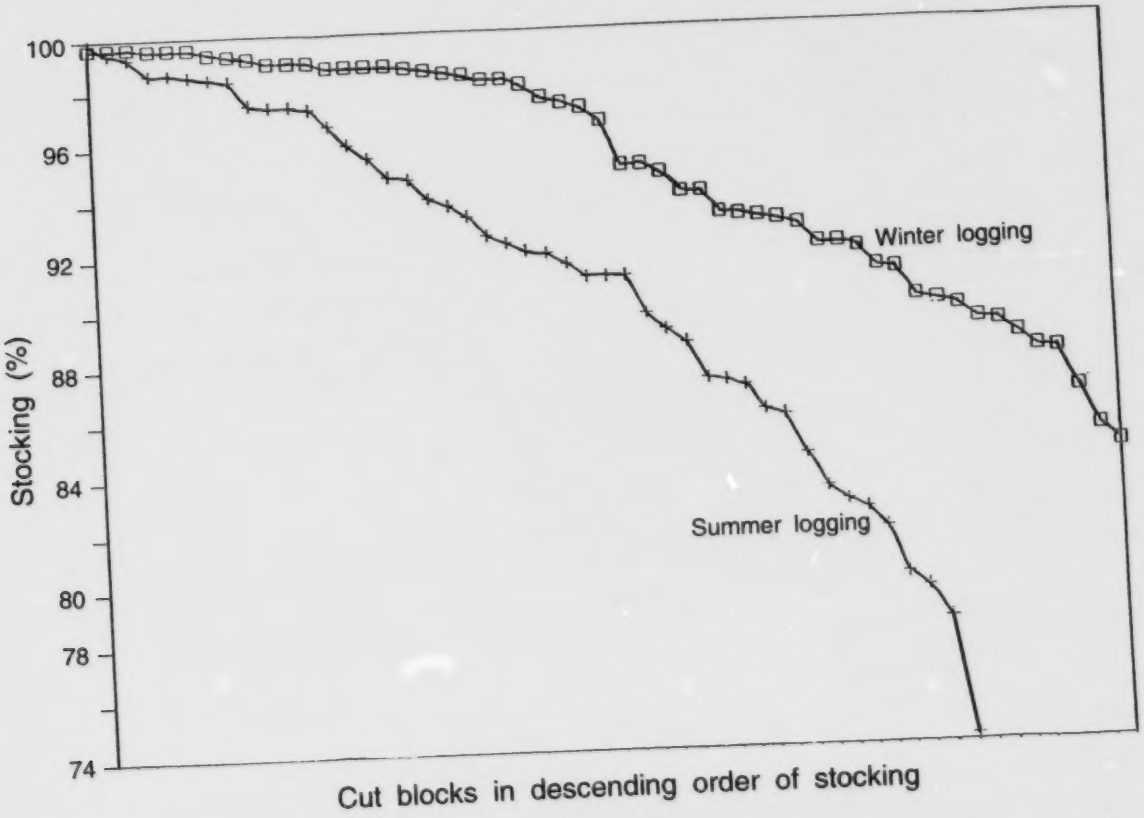

Figure 3. Stocking of deciduous cutovers after winter and summer logging, Edson Forest, Alberta. (T. Sikora and M. Pugh, Alberta Forest Service, personal communication.)

establishment. The causal relationship of soil compaction and aspen regeneration has not yet been fully documented (see also Alban 1991 in these proceedings).

In a recent NoFC study height growth of aspen suckers on skid trails where only minimal changes in aspen density were present but where depressed skid wheel marks were still detectable years after harvest was assessed. Height growth of aspen in the depressed zones showed a declining trend compared to the growth of aspen in an adjacent area (Fig. 4).

The importance of such an observation is not clear, and generalizations should be avoided. It is plausible, however, that the observed difference in height growth could increase with time. Compaction effects are known to be long-lasting and to increase over time. Corns (1988) observed significant reductions in the growth of lodgepole pine and white spruce seedlings with increased bulk densities and postulated that compaction effects on tree growth may not become evident until 10-12 years after establishment when the young tree roots start exploiting soil at depths of 20-30 cm. Furthermore, Corns (1988) estimated that soil compaction in the boreal forest of Alberta may persist for several decades due to specific characteristics of local soils.

From a stand productivity viewpoint, the impact of reduced growth on localized areas of skid trails may be negligible. In mature aspen stands, trees are spaced roughly 4 m apart. The space above the skid trails should be filled by the crowns of trees from the adjacent areas without adversely affecting yield at harvestable age.

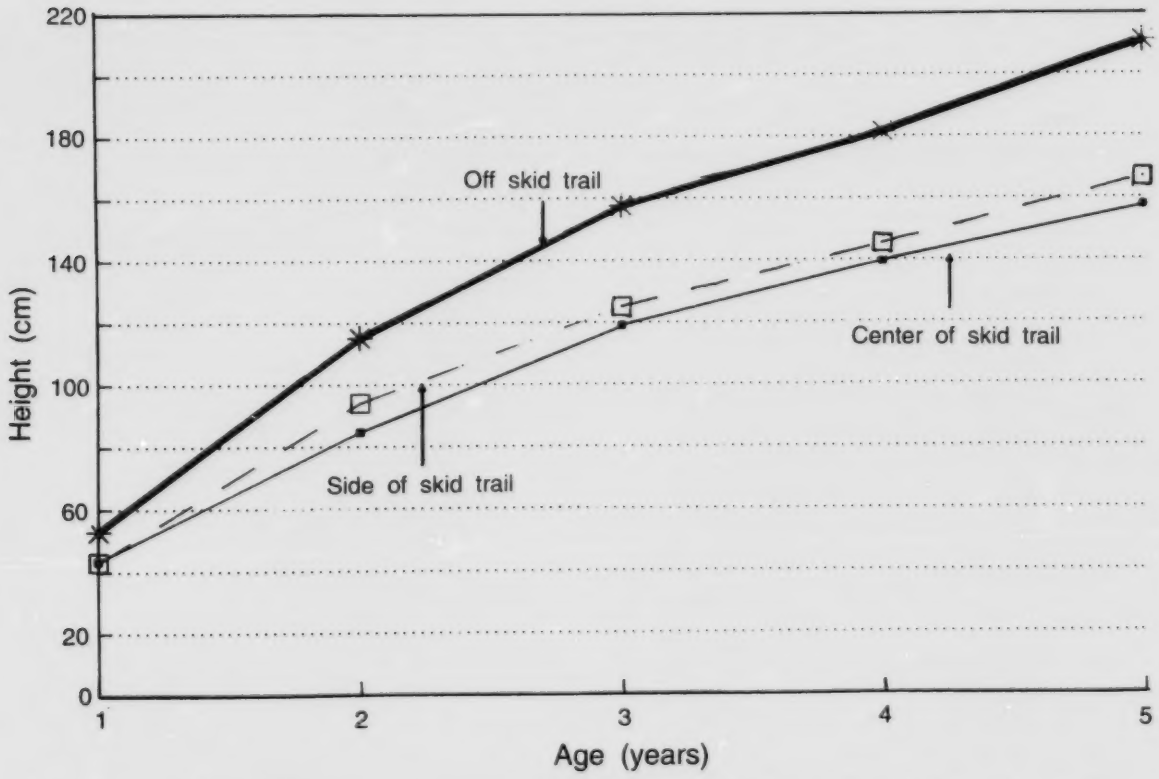

Figure 4. Height growth of aspen suckers on skid trails and adjacent, undisturbed area. A case study of the 7 cut blocks, Edson, Alberta.

Root Disturbance

In most cases, summer logging with heavy equipment is very damaging to aspen roots, particularly when soils are wet. The roots from which most aspen suckers regenerate are within 6-8 cm of the soil surface and are very vulnerable to physical damage and displacement.

Concerns that forest floor disturbance associated with harvesting could significantly affect the quality of aspen regeneration are not new. Zasada and Tappeiner (1969) assessed soil disturbance caused by rubber-tired skidders during summer logging in Minnesota. They found 75% of the soil surface undisturbed or only slightly disturbed. About 10% of the area was heavily disturbed, with skid trails deeply rutted and roots damaged to a depth of 10 cm or more. This type of damage can develop with only a few skidder trips when the soil is wet. Despite lower suckering observed in heavily disturbed areas, they concluded that this type of disturbance would not result in portions of the new stand being understocked.

Aspen regeneration and ingress on heavily disturbed areas adjacent to the extraction road were assessed recently in a case study of seven hardwood cut blocks in the Edson Forest. The results are shown in Figure 5. There was a low (40-60%) stocking of aspen seedlings and suckers; the percentage increased slightly as the distance from the extraction road increased. In contrast, the average stocking of aspen suckers in the bordering area was 98%. Aspen suckers in the heavily disturbed area had a variable height. Fragments of aspen roots present in the heavily disturbed area, likely deposited by the respreading of organic debris, did not support normal sucker development and growth. Similarly, aspen seedlings were mostly under grass cover, and their growth was less than that observed in young seed-origin aspen in the foothills of Alberta[1].

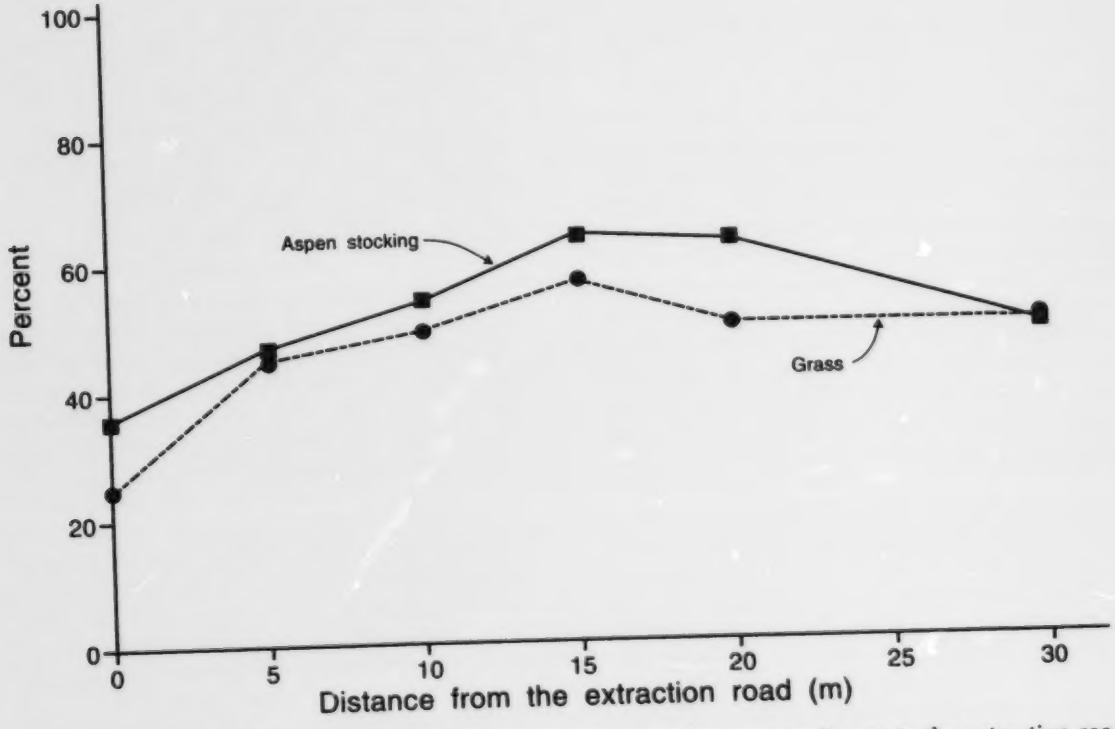

Figure 5. Aspen stocking and grass cover on heavily disturbed areas adjacent to the extraction road. A case study of 7 cut blocks, Edson, Alberta.

[1]Navratil, S. 1989. Unpublished data.

Based on this case study it appears that heavily disturbed areas, such as landings on hardwood cut blocks, are slowly colonized by ingressing aspen but do not regenerate to acceptable standards despite landing rehabilitation attempts.

Some heavily disturbed areas could be designated for permanent skid trails or revegetated for something other than aspen production. In northeastern British Columbia, it was estimated that landings occupied an average of 5% of cutover land and that skid roads occupied an average of 16% (Carr 1987, cited in Peterson et al. 1989).

Excessive Soil Moisture

It was observed as early as 1911 (Weigle and Frothingham 1911) that air is needed to stimulate sucker production from aspen roots. The observations that aspen requires a proper balance between soil moisture and soil aeration to survive and reproduce has often been noted but rarely documented in the literature.

Regeneration failures have been observed in Colorado where clearcutting of aspen stands raised the water table, causing suckering failure and subsequent sucker mortality (Crouch 1986). Bates et al. (1990) in Minnesota observed the high incidence of poor regeneration on level sites and attributed it to excessive wetness on sites due to poor drainage and high water tables, particularly in the early summer. Sims et al. (1990) also noted that vegetative reproduction of aspen is inhibited by flooding immediately after a disturbance. In addition, it is also known that water tables less than 60 cm from the surface decrease aspen growth (Adams and Gephart 1990).

It is very likely that excessive soil moisture after harvesting is one of the main reasons for localized aspen regeneration deficiencies and for the expansion of balsam poplar observed on hardwood and mixedwood sites in the prairie provinces. Data on the critical levels and critical duration of excessive soil moisture affecting suckering reproduction are lacking. In a greenhouse study, Maini and Horton (1964) illustrated that only well-aerated aspen root cuttings are capable of producing suckers and that roots succumb when the soil is saturated. Work is needed to determine how harvesting changes the water table level and drainage patterns on fresh and moist sites, and how the changes affect aspen and balsam poplar regeneration.

Minimizing Harvesting Impacts

Site disturbance associated with the extraction of wood from the forest can have either favorable or unfavorable effects on the amount and vigor of aspen regeneration. Detrimental impacts can occur in several forms—excessive soil moisture, soil compaction, and root disturbance—all of which are closely linked to site characteristics.

Operational guidelines for softwood harvesting prescriptions to minimize site degradation are available in Alberta, British Columbia, and elsewhere (Rothwell 1978; Lewis and Carr 1989). General recommendations of how to mitigate harvesting impact apply equally to aspen regeneration. Winter logging on frozen ground and snow cover can prevent excessive soil compaction and root disturbance. High flotation tires can reduce soil disturbance in summer harvesting. Since soils become more susceptible to compaction and root damage as their moisture content increases, harvesting operations should cease on heavy textured soils during wet weather and spring breakup.

The benefits and costs of mitigating harvesting practices could be better balanced and justified once impacts are reliably quantified. As Dave Alban points out in his paper at this symposium, there is an urgent need for studies that quantify key soil factors and assess management impacts on aspen regeneration and site productivity.

Observations from field surveys indicate that the attributes of sites sensitive to harvesting-induced regeneration problems can be identified. Site sensitivity to soil compaction, puddling, and erosion is also included in management interpretations of forest site classification guides (Corns and Annas 1986; Delong 1988; Racey et al. 1989). A hazard rating system specific to hardwood and mixedwood sites and aspen regeneration could be developed to guide regeneration and harvesting prescriptions.

REGENERATION STANDARDS

One of the most pressing tasks for forest managers and researchers alike is to develop new, or refine existing regeneration standards for aspen and hardwood regeneration.

The aspen stands of tomorrow will be judged by different and probably higher standards. Concerns about the quality of future stands may demand criteria such as growth rate, stem defects, and tree form in addition to customary density and stocking data.

Aspen sucker stands have several unique features that may require regeneration standards which are different than those primarily addressing conifer regeneration.

Rapid Decline in Densities

High initial densities following clear-cutting are rapidly reduced by the differentiation of sucker clumps and high mortality induced by competition. Rapid reduction in densities occurs especially in the first 8 years of sucker stand development (Fig. 6). For this reason careful attention needs to be given to the timing of regeneration surveys.

Minimum Acceptable Density and Stocking

The age-density curves shown in Figure 6 converge at 20 years. Based on the similar converging trends reported for young aspen stands, Peterson et al. (1989) concluded that there is a wide range of acceptable early stand densities for aspen because the large initial differences diminish by age 20.

Defining acceptable minimum density and stocking levels is difficult. Recommendations in the literature vary from 2500 stems/ha to 23 000 stems/ha. Doucet (1989) suggested that a stand must contain at least 10 000 stems/ha at 2 years (Perala 1977) or 6000 stems/ha at 3 years (Steneker 1976) to be considered adequately stocked. The difficulty is that very little is known about the development of sucker stands established at low and irregular initial densities and stocking. Much current knowledge comes from research plots that are usually deliberately located to avoid nonstocked spots and to provide uniform stocking.

Site-adjusted Regeneration Standards

Competition and shading reduce sucker density to a level and at a rate commensurate with site capability. Modeling approaches for estimating stem survival of aspen suckers document the need for inclusion of site variables (Perala 1973; Ek and Brodie 1975). Consequently, the guidelines for acceptable density levels of sucker stands should be site-specific and targeted to local yield tables and yield predictions. The example of stand densities at age 20 summarized in Table 1 illustrates the extent of site and regional differences and reinforces the need for site-adjusted regeneration standards.

Relationship of Stocking and Density in Sucker Regeneration

Stocking, a measure of the proportion of the area occupied by trees of a given age (Ford-Robertson 1971) and density, a number of seedlings per defined area, are related but not synonymous. A number of functions for density and stocking relationships have been developed for different species and cover types (Bella 1976; Bella and De Franceschi 1978; Bever and Lavender 1955; Weetman and Frisque 1977). These functions are used for estimating density from stocking, largely for coniferous regeneration of seed origin. The spatial distribution of sucker regeneration may be different. Regeneration survey procedures derived for conifers should be re-examined to ensure that they account for the clustering and clumpy distribution of suckers and for voids of aspen root systems. Where tree spatial patterns tend to be clumpy, Bella and De Franceschi (1978) recommend using large plots (10 m^2 and over).

ASPEN REGENERATION IN MIXEDWOOD SILVICULTURE

Regenerating aspen mixed with conifers or with other hardwoods is as yet very rarely an objective. Despite the lack of management objectives, the amount of mixed regeneration on aspen and mixedwood sites is increasing in the

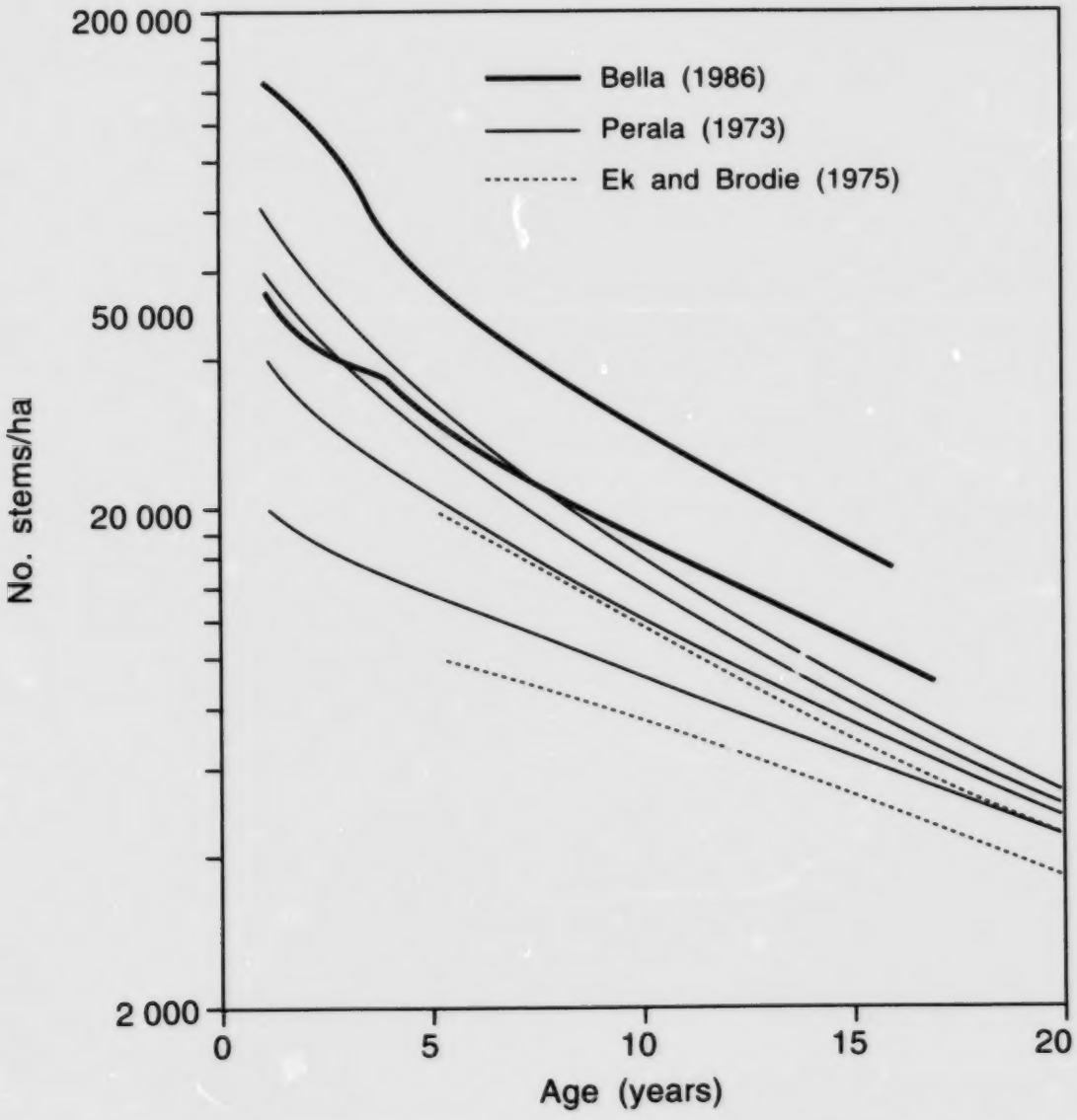

Figure 6. Density and age relationship in aspen sucker stands. Adapted from Perala (1973), Ek and Brodie (1975), and Bella (1986).

Table 1. Number of stems per hectare in 20-year-old aspen sucker stands on different sites

Site	Alberta[1]	Alberta[2]	Ontario[3]
	Stems/ha		
Good	9 270	10 734	2 525
Medium	12 350	13 057	2 993
Poor	17 000	15 882	4 119

[1]McLeod (1952, cited in Peterson et al. 1989).
[2]Site indexes 16, 20, 24 m at age 50 (Bella and De Franceschi 1980).
[3]Plonski (1974).

region. From an ecological viewpoint this is not surprising, but it does present a number of regeneration and management challenges. Several of these have been recognized as important subjects of silviculture research (Navratil et al. 1989, 1990) and of policy and regulation issues (Expert panel on forest management in Alberta 1990).

We need to learn how to manage the stand as a mixedwood by maintaining or enhancing the component of other species present.

Prescriptions for enhancing the conifer component in mixedwood stands at the expense of aspen have been intensively studied. Work on aspen control has provided technologies for manipulating aspen density at stand establishment. Release techniques applied at later stages of aspen-conifer mixtures leave some unanswered questions related to aspen regeneration. For example, there is a void of knowledge on resprouting of cut juvenile aspen, its growth rate, and its quality if it is allowed to form a component in the future mixed stand.

New research is addressing knowledge gaps concerning mixed hardwood stands. These initiatives focus on balsam poplar and white birch regeneration, their growth rates and interspecific competition, and stand development in aspen-hardwood mixtures.

CONCLUDING REMARKS

Can we meet the challenge?

From the silviculture viewpoint, I believe we can. But we will have to adapt our guidelines and practices, some of which were mentioned previously.

"It's a healthy thing now and then to hang a question mark on the things you have taken for granted" Bertrand Russell

The current understanding of aspen reproduction biology is very thorough, and sound foundation knowledge gained from research and practice has been laid. Field foresters have started using available knowledge and are gaining confidence in meeting the challenge. We must avoid, however, the complacent attitude, "we know it all." The challenge might become difficult if we disregard known silvicultural and ecological principles and do not enhance our knowledge in many areas deserving research.

The seemingly simple decisions to be made concerning aspen regeneration require the integration of several components.

No single factor affecting aspen regeneration can be considered alone. To put it simply, sound aspen regeneration depends on the integration of species silvics; site classification; on-site stand level prescriptions; and precise planning of harvesting operations, before harvesting begins.

The human resource is important

To cope with the increasing demand for expertise and to ensure that available information is used, we must provide appropriate modes of training and information transfer. Foresters do not have time to go through

voluminous literature; I myself have over 250 publications on aspen. The aspen monograph in progress (see the paper "Learning from the past for the future" in this proceedings) will help. So will the knowledge bases and Aspen Decision Support System applicable to the boreal forest region that are currently being developed at the Northern Forestry Centre in Edmonton.

"You cannot acquire experience by making experiments. You cannot create experience. You must undergo it." Albert Camus

Forestry is a discipline very much based on experience. Aspen regeneration is a relatively new forestry practice, with a short tradition in most of the region. We should encourage foresters, land managers, and public groups to travel to see regions with long-term aspen management. This in turn should foster the acceptance of aspen regeneration practices and the avoidance of pitfalls.

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THE ROLE OF BALSAM POPLAR IN ASPEN MANAGEMENT

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ABSTRACT

Balsam poplar is the second most prominent deciduous species in the boreal mixedwood forest of Alberta. It represents a significant proportion of the deciduous inventory, most often in association with trembling aspen. Recent increases in aspen harvesting have focused new attention on the less desirable poplar species. The role of balsam poplar in aspen management is essentially determined by its level of use.

INTRODUCTION

When one reads about the contemporary topic of deciduous utilization in Alberta, it is assumed the subject is trembling aspen (*Populus tremuloides* Michx.). The significance of other poplar has often been overlooked, and only in recent years has the distinction of species been made. Balsam poplar (*Populus balsamifera* L.) is the next most important deciduous species in Alberta, representing about 15% of the provincial deciduous inventory[1]. Because most of it grows in association with trembling aspen to varying degrees, it inevitably plays a role in aspen management. Balsam poplar use is currently minor relative to trembling aspen; however, the recent boom in deciduous use has brought new attention to the species, primarily out of necessity (e.g., wood supply).

Winship, R. 1991. The role of balsam poplar in aspen management. *In* S. Navratil and P.B. Chapman, editors. Aspen managment for the 21st century. Proceedings of a symposium held November 20-21, 1990, Edmonton, Alberta. For. Can., Northwest Reg., North. For. Cent. and Poplar Counc. Can., Edmonton, Alberta.

Information and research on the management of balsam poplar and its relationship to aspen management is not well known, at least to this author. This paper therefore relies mostly on the experiences of an aspen manager who currently does not utilize balsam poplar.

THE UNDESIRED POPLAR

Before one can define the role of balsam poplar, a brief review of why it is less desirable than trembling aspen is in order. Traditionally, the properties and characteristics of balsam poplar relative to trembling aspen have been learned from studies on trembling aspen alone or on poplars in general. Only recently have direct comparisons been made. These primarily relate the wood properties to manufacturing a product. While reading through research on this subject, I drew some general conclusions about the characteristics of the two species: 1) certain differences are not as significant as once assumed; 2) variability is high at the species and tree level, making comparisons more difficult; and 3) balsam poplar may in fact be comparable or even superior to trembling aspen in some respects.

The following is a brief summary of the characteristics of balsam poplar relative to those of trembling aspen. Specific references follow each characteristic.

1. Balsam poplar has a lower density (Singh 1987; Cyr and Laidler 1987).
2. Balsam poplar has a higher moisture content (MacKay 1974; Cyr and Laidler 1987).

[1]Source: Personal communication, October 1990, from T. Lakusta, Timber Management Branch, Alberta Forestry, Lands and Wildlife, Edmonton, Alberta.

3. There is less advanced decay in standing balsam poplar, but the trees are more prone to discoloration (Paul and Etheridge 1958; Bailey and Dobie 1977; Northern Alberta Development Council 1985).
4. Balsam poplar has shorter, wider fibers than trembling aspen. It is also more gelatinous (Pfaff 1988) and has wider vessels (Micko 1987).
5. It has a higher lignin content (Cyr and Laidler 1987).
6. It has more bark than trembling aspen (Micko 1987; Pfaff 1988).
7. There is less above-ground biomass for a given tree size for balsam poplar (Johnstone and Peterson 1980; Singh 1982).

The use of balsam poplar in Alberta is currently restricted to lower-grade lumber products. The major Alberta aspen uses, namely oriented strand board (OSB) and chemithermal-mechanical pulp (B/CTMP), are not currently utilizing balsam poplar on an operational scale. Using balsam poplar for OSB may result in reduced effectiveness of waferizing, reduced board strengths, increased potential for thickness swelling, and increased drying requirements (Pfaff 1988). Higher resin content and longer processes can compensate for these things, but at some cost. Using balsam poplar for CTMP may result in a reduced brightness factor and lower yields, although most strength tests are comparable to aspen (Enotech 1987). There is currently one bleached kraft pulp mill in Alberta capable of using both aspen and balsam poplar to defined limits, and another one has been proposed.

STRATEGIES

It is important to put the distribution of the balsam poplar component into perspective before considering its role. It is well known and documented that balsam poplar prefers moister sites than aspen, and it usually precedes the succession to white spruce on such sites (Corns and Annas 1986). The Alberta aspen user, however, is more likely to encounter balsam poplar as a highly variable mix in predominantly deciduous operating areas. A balsam poplar content (stand composition) of 30% or more for a given harvested area is quite common. Simply trying to determine where and how much balsam poplar is a major task, as another speaker at this symposium will attest to. The point being made here is that aspen harvesting operations no longer have the luxury of avoiding stands with low-quality aspen or high balsam poplar content. If a deciduous stand is merchantable (i.e., if it has a sufficient yield of trembling aspen), it falls in the lap of the aspen manager. The role of balsam poplar can therefore be defined by its level of composition and utilization in areas managed for aspen. Defining the role will then result in specific strategies as follows.

No Utilization

As stated, most deciduous operations in Alberta currently do not utilize balsam poplar; therefore, the traditional strategy is one of avoidance. This begins with identifying the balsam poplar concentrations in a given planning area. Pure stands of balsam poplar that will not be used can be incorporated as breaks, or retained wildlife habitat, in a harvesting pattern. Where balsam poplar occurs within a cut block, the procedure is retention on the stump. The residual trees, if there are enough of them, provide the cover needed by browsing ungulates and can possibly offer sites for cavity nesters. One immediate benefit of retention is aesthetic. Any residual trees lessen the psychological impact of clearcuts in the eye of the general public. It should be noted that this strategy reduces harvesting productivity.

Needless to say, retention of balsam poplar trees after harvesting contradicts a sound silvicultural strategy. The residual balsam poplar hinders regeneration, and in combination with other factors, can result in insufficient aspen regeneration or eventually an increase in the balsam poplar content (Navratil et al. 1990). This concern is receiving more attention because the larger deciduous operators in Alberta now have deciduous reforestation responsibilities. In fact, the province of Alberta has established a guideline on the level of retention to address this concern. The alternative of simply felling but not using the balsam poplar trees is no more desirable in that it creates the usual hazards and hindrances associated with heavy slash and can be construed as wasted timber.

Utilization

The more ideal situation, of course, is to use both species in one harvesting operation. If the strategy is to restrict harvesting to predominantly aspen stands but to utilize any incidental balsam poplar, the assumption is that the regenerated stand will produce the same species composition. Bella and DeFranceschi (1972) indicated this might be the case, but it is certainly worth more evaluation as regeneration survey information develops. It has been this author's observation that balsam poplar seedlings are often the first to establish on bared and reclaimed logging sites such as roads and landings. Presumably, this is due in part to a local seed source in residual trees and because balsam poplar is more effective in regenerating from seed. This possibility in combination with changes in site conditions created by harvesting may influence the composition of the next stand. In fact, it may be more opportune to enhance deciduous reforestation efforts by planting balsam poplar cuttings, instead of coniferous species, on severely disturbed sites of deciduous cutovers, because this species is more readily propagated (Maini 1968).

The next strategy would be to implement practices that promote aspen over balsam poplar in the regenerating stand, if aspen is more preferable for a given product. A preharvest kill of balsam poplar trees in a deciduous stand, using techniques such as girdling or herbicide injection, is conceivable. This would restrict vegetative regeneration from this species but still provide for its utilization.

The importance of species composition in regenerated stands should not be overlooked. If balsam poplar costs more to use, one does not want to significantly increase its proportion of the inventory. Conversely, we do not want to dramatically reduce it without evaluating the ecological impact. Like the forest industry, the forest tent caterpillar and browsing ungulate seem to prefer aspen, but that is probably the extent of our knowledge at this time.

A higher level of utilization would, of course, involve the harvesting and management of balsam poplar stands as well as aspen stands. The significance of this statement is that there is much we need to know about the growth and yield of the balsam poplar species in Alberta. The current assumption is that what we know of aspen we apply to balsam poplar, yet its stand development and longevity is clearly different from aspen. It therefore might warrant other management strategies (e.g., rotation age).

CONCLUSION

Speaking as a forester, I hope we will be able to discuss true deciduous management, as opposed to aspen management, in the near future. For the time being though, trembling aspen remains the preferred species. Those of us who utilize aspen will unavoidably encounter balsam poplar. As we develop into aspen managers, we must ultimately define the role of balsam poplar.

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ASPEN INVENTORY: PROBLEMS AND CHALLENGES

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ABSTRACT

The inventorying of aspen (*Populus tremuloides* Michx.) and associated species poses problems more challenging than those involved in coniferous stand inventory. Those problems include species differentiation, the detection and quantification of coniferous understories, the determination of individual tree and stand ages and net volume. Inventory updating between inventories is also more difficult. Inventory cost and accuracy can be affected and inventory projection uncertain.

INTRODUCTION

Most forest management activities are based directly or indirectly on forest inventory information. How effectively aspen and its associated species are managed therefore depends on the success achieved in inventorying.

To set the stage for my comments on aspen inventory problems I'd like to briefly review forest inventory procedures as they are commonly practiced in Canada.

The inventory process can be divided into four broad activities. First, the area to be inventoried is usually stratified or divided into homogenous vegetation types or polygons to reduce the cost of field sampling and to facilitate forest mapping. Remotely sensed imagery is normally used for stratification.

Secondly, field sampling is conducted to obtain data on individual tree, stand, and stratum variables such as tree size, tree form, tree defect, stand volume, stand species composition, and variance within and between stands. Measurements of both standing and felled trees are usually taken.

Thirdly, the area and point data are combined and statistically analyzed to provide reports of stand and strata composition including gross and net timber volumes by tree species and other information.

Finally, because an inventory provides only a snapshot of the condition of the resource at the time of inventory, an inventory must account for forest depletion (e.g., harvesting) and growth between successive inventories.

Now that I've outlined in simplistic terms the forest inventory process I'll address each of the inventory activities in more detail and describe the special problems inherent in inventorying aspen.

FOREST STRATIFICATION

Species Differentiation

The identification of tree species composition is one of the first objectives of a forest inventory. Despite the appearance in the last 20 years of high-tech equipment such as digital scanners mounted in satellites and aircraft, forest stratification is still largely done by manually interpreting aerial photography due to the associated cost and resolution advantages. Unfortunately, within that portion of the electromagnetic spectrum reflected by vegetation and imaged by film there is little discernible difference between aspen (*Populus tremuloides* Michx.) and balsam poplar (*Populus balsamifera* L.). That fact should not be surprising given that the two species belong to the same family. White birch (*Betula papyrifera* Marsh.) is also

Morgan, D.J. 1991. Aspen inventory: problems and challenges. *In* S. Navratil and P.B. Chapman, editors. Aspen managmeent for the 21st century. Proceedings of a symposium held November 20-21, 1990, Edmonton, Alberta. For. Can., Northwest Reg., North For. Cent. and Poplar Counc. Can., Edmonton, Alberta.

difficult to distinguish from the other two hardwoods. The interpreter must use very subtle differences in crown appearance, supplemented by considerable field checking, to successfully separate the hardwood species.

In northern Alberta, interpreters can also take advantage of site differences. In the north balsam poplar is usually found in relatively pure stands on wet sites, and it commonly occurs along water bodies. In central Alberta, where the bulk of the forest industry using aspen is concentrated, the two *Populus* species unfortunately tend to occur together in stands of varying composition.

Success in separating aspen and balsam poplar using other types of remote sensing has been limited. High-resolution MEIS imagery and specially developed digital enhancements are being assessed. Preliminary results[1] suggest that birch is readily identifiable, but the difficulty of discriminating aspen from poplar remains. Imagery for the full spectral range that MEIS can record was not available for the test. High-resolution sensors like MEIS create large volumes of data, and the cost of data acquisition and analysis is high. This technology requires further research before operational use will be practical. Only with large-scale aerial photography at scales large enough that differences in branching habit can be discerned (1:5000 or larger) have interpreters been able to reliably distinguish between the two tree species. The cost of using such photography for forest stratification is prohibitive.

The new Alberta Vegetation Inventory, conducted on behalf of Alberta Forestry, Lands and Wildlife, is based on photo-interpreted aerial photography. In preparation for that inventory, the ability of photo interpreters to separate hardwood species on a number of photo scales and film emulsions was tested. Only limited success was achieved (Silvacom Ltd. 1987). Agfa 200 film at a scale of 1:20 000 was eventually selected based on a combination of interpreter accuracy and cost. Extensive and costly field checking by the photo interpreters is still required to achieve the desired accuracy of species differentiation.

The problem of hardwood species differentiation using remotely sensed imagery thus remains unsolved. The challenge is to find affordable imagery that will enable us to reliably and accurately identify tree species composition in forest stands.

Spruce Understory

A second inventory problem in the remote sensing area is the need to delineate, at an affordable cost, areas where spruce understories occur under deciduous overstories. Arguably the most useful inventory variable from a forest manager's perspective is tree height. Accurate determination of hardwood tree height using aerial photography requires that the leaves be present. Hardwoods in full leaf largely or totally obscure the presence of spruce understories. One would have to use imagery acquired twice for the same area, once during hardwood leaf-on and once in the leaf-off period, to get an idea of hardwood tree height and the spruce understory. Both sets of imagery would have to be interpreted. Using only aerial photography, this procedure would be costly and time consuming. A feasible alternative for understory definition may be satellite imagery from the leaf-off period supplemented by ground sampling. This approach is now being investigated. Other alternatives such as aerial sketching or extensive ground checking are too inaccurate to meet management needs or too expensive or both.

The detection and quantification of conifer understory is important for the determination of land base and the calculation of annual allowable cuts. The problem (and the challenge) is again that of developing affordable technology that meets forest management needs.

Regeneration Surveys

Due to the high cost of field work, aspen regeneration surveys based on remotely sensed imagery supplemented with limited field-checking are under consideration. The use of large-scale aerial photography for assessing coniferous regeneration has been well researched (Hall et al. 1984; Aldred and Hall 1990). Its usefulness for monitoring hardwood

[1]Hall, R.J. 1989. Summary of MEIS enhancement methodology for forest cover type discrimination. For. Can., North. For. Cent., Edmonton, Alberta. File Rep. NOR-02-03.

regeneration is still to be assessed. Probably no other form of remotely sensed imagery is capable of providing the detailed information that will be needed. A methodology that includes ground sampling will have to be developed.

Insect and Disease Losses

Insects and disease can have a significant effect on aspen stand productivity. Reliable estimates of the annual volume losses due to such pests are unavailable. "For Canada these losses may equal, on average, the annual losses attributed to forest fires" (Volney 1988). These losses will be hard to quantify unless we can find a way to define the area affected using remotely sensed imagery.

Insects

Three insect defoliators are credited with causing most of the aspen volume loss attributable to insect attack. The best known of the three is the forest tent caterpillar (*Malacosoma disstria* Hüb.). Any forester familiar with aspen is aware of the massive defoliation that can occur, often several years in a row, when forest tent caterpillars attack. Stem-wood production may be drastically affected (Mattson and Addy 1975) even when the trees produce a second crop of foliage. The cumulative effect of years of defoliation can be serious. Repeated severe defoliation may cause tree mortality directly or result from secondary pests such as *Hypoxylon* spp. infections (Churchill et al. 1964) that act in combination with the defoliation.

A second prominent insect defoliator of aspen is the large aspen tortrix (*Choristoneura conflictana* Walk.). Although this pest generally does less harm than the forest tent caterpillar, the damage can be significant. This species also affects the area north of Manning, where the forest tent caterpillar rarely occurs[2].

A third important aspen defoliator is the Bruce spanworm (*Operoptera bruceata* Hulst), a pest few foresters are familiar with as the last major outbreak occurred in the 1960s.

Defoliation places stress on the trees affected, particularly when attacks are followed by other pathogens or drought. That stress may lead to increased decay, although the connection has not been proven[2].

Forest management agencies in Alberta have not attempted to estimate aspen losses caused by insect defoliation. We don't monitor the extent and severity of outbreaks except in a general way by aerial sketch mapping of defoliated areas because aspen was not considered important until recently, and because of the prohibitive cost and difficulty inherent in getting accurate damage estimates. The time "window" between maximum defoliation and the flushing of the replacement leaves is often too short (3-6 weeks) to reliably obtain aerial photography of the affected areas. Researchers have shown that mapping of the extent of defoliation is feasible using satellite imagery (Hall et al. 1984). An operational multistage approach should be developed. First, however, researchers may have to demonstrate the negative effects of defoliation on the growth of aspen to justify the expense of monitoring.

Disease

Unlike coniferous trees, aspen and poplar stands often contain substantial amounts of internal defect, enough to inhibit the industrial use of many stands. Researchers have attempted to relate the occurrence and extent of internal defect (stain and decay) to many factors, including site variables and stand age, with little success. Stratification by decay level is therefore very difficult. The weakness of the statistical correlations may be partially due to the high level of variability of decay levels both within and between stands.

The lack of correlation with age is a serious problem given our need to predict future merchantable stand volumes. Our lack of success may be partially attributable to our assumption that aspen stands are even aged. In a decay study conducted near Whitecourt, Alberta, Maier and Darrah (1989) found that tree

[2]Personal communication, November 1990, from H. Cerezke, Head, Forest Insect and Disease Survey, Forestry Canada, Northwest Region, Edmonton, Alberta.

ages in older stands varied substantially. The younger trees were often hard to distinguish from their older companions without careful aging.

Because little relationship between stand decay levels and stand variables has been found, stratification of stands by potential decay levels using remote sensing techniques is not possible. This makes decay very difficult to deal with during an inventory.

FIELD SAMPLING

Once stratification of the area to be inventoried has been completed, field sampling can begin. Aspen stands also present special problems and challenges in this phase of an inventory.

Age Determination

The first problem relates to the difficulty of accurately determining the age of aspen trees. Diffuse, porous trees lack the distinct difference between spring and summer wood exhibited by Alberta conifers. The wood usually requires special treatment to make the growth rings more obvious. There is fully reliable methodology to do this. The problem is further complicated by the occurrence of "false" growth rings (probably due to insect defoliation) and by the frequent occurrence of rot in the butt section of aspen trees.

Age determined at breast height, at stump and/or at germination point is critical for many inventory and growth estimation purposes. For example, site index, an indicator of site productivity, is based on the height of trees when breast height age was 50 years. If age cannot be determined accurately, growth projection becomes very uncertain. Harvest planning also requires knowledge of stand ages.

Tree Height

The heights of standing coniferous trees are often determined inaccurately due to the limitations of the equipment used, the difficulty in seeing the tops of the trees, and often carelessness. Measuring of hardwood trees like aspen presents an even greater opportunity for error because the peak of the crown can seldom be seen clearly. Aspen tree heights are often overestimated because a point on the near upper side of the crown, closer to the observer than the top of the tree, is used as a sighting point.

Tree Form

The form of individual trees must be determined to accurately estimate individual and stand gross and net volumes. Because of aspen's branching habit, it is difficult to consistently measure tree form, even on felled trees. This problem is compounded because utilization standards for aspen frequently change as the forest industry develops new manufacturing processes. Which branch (if any) should be considered an extension of the bole? How far should branches be traced? At what top diameter should measurement cease?

Decay Determination

The extent and type of decay in trees can only be determined by felling, sectioning, and measuring the decay present. In the past, researchers and foresters did not use a standard methodology for assessing internal tree defect. This has contributed to the variation in defect estimates reported by different researchers. Also, the differences in the effects of the various organisms on the type, extent, and rate of spread of decay was seldom appreciated. Internal tree defect has traditionally been categorized as stain, incipient decay, and advanced decay. We assumed that we were dealing with a continuum from stain to advanced decay. This is seldom the case. A variety of organisms cause wood stains. Some cause no further damage to the affected trees. Attack by others leads to advanced rot (e.g., *Phellinus tremulae*, the most common cause of rot in aspen trees). Other fungi, such as *Peniophora polygonia*, only cause incipient rot.

The problems in data analysis and prediction that can result when the defect-causing organism is not recognized are obvious. In response, the Alberta Forest Service and Forestry Canada jointly developed references (Hiratsuka et al. 1989; Hiratsuka et al. 1989 [unpublished report])

designed to help users identify what organism is in a defective tree. The user can then better estimate current and future defect levels for different end products. Use of these references should also help to standardize the measurement of internal tree defect. This will make pooling defect data easier and will legitimize comparisons between different surveys. It may also enable us to discern patterns in defect occurrence and progression and hence facilitate defect prediction.

STATISTICAL ANALYSIS AND REPORTING

The problems related to stratification and field sampling compound to make aspen inventory data analysis and reporting both difficult and expensive. If the population (i.e., aspen stands) can't be stratified into reasonable classes, analysis of the data and subsequent reporting will not yield the information detail or the level of accuracy desired by forest managers.

INVENTORY UPDATING

A description of forest inventory problems would be incomplete without reference to inventory updating. Forest inventories are usually redone on a regular basis to record changes in the forest resource. Between inventories, some method that accounts for at least gross changes in the resource is required. Updating activities can be broadly divided into two categories: those related to depletion and those related to growth.

Depletion

Updating for significant losses caused by forest fires, harvesting, and other factors is usually based on interpreted aerial photography. Where the boundaries of the depletion areas are obvious (e.g., cut blocks), this approach can be effective. It can also be costly and slow. Researchers have demonstrated that using satellite imagery can be cost effective for conifer depletion updating (Hall et al. 1989). Areas where only part of the timber is lost (e.g., selective logging or insect attack) are often not handled well. In these times of tight budgets and timelines the use of satellite imagery for updating hardwood depletions needs to be researched further to see if acceptable accuracy levels can be attained.

Growth

Very few agencies have a mechanism for updating their inventories to account for aspen growth between inventories. This can be attributed partly to the lack of interest in the species in the past. Only recently have agencies begun to establish the permanent sample plots required to provide a data base for the development of growth models.

Growth modeling of aspen and poplar will be more difficult than that for most conifers because the model will have to accommodate ingress and the eventual taking over of some stands by tolerant conifers, notably white spruce (*Picea glauca* [Moench] Voss). The change from an apparently pure aspen stand to a mixedwood stand can occur rapidly if one lacks a method for tracking spruce understories. Too little is known at this time about the interactions of these species to enable accurate modeling.

Our lack of knowledge about insect and disease attack on aspen also limits our ability to model aspen growth.

CONCLUSION

Today I have tried to briefly describe some of the problems inherent in inventorying aspen. Collectively they inject an increased level of uncertainty into the inventory of hardwood stands versus those involving pure coniferous stands. They also affect our ability to estimate the condition and extent of the growing stock in the short- and long-term. The challenge we face is that of finding innovative, affordable solutions to these problems that will enable us to manage Alberta's hardwood resource in an effective and responsible manner.

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ASPEN INVENTORY AND ALLOWABLE CUT

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ABSTRACT

Much effort has gone into gathering forest inventory information as a basis for setting aspen allowable cuts in Alberta. The volume and other attributes of standing timber, as described by conventional forest inventories, are important in determining cut levels; however, in a province where sustained-yield management is required by law, cut levels are also influenced by land use and yield regulation policies and growth and mortality rates of existing and future stands. Ignorance of how these factors interact to influence future forest conditions and wood flows potentially creates a more serious gap in our knowledge than do limited inventory techniques. This argument is illustrated with examples from Alberta forest management areas.

THE ASPEN FOREST

The expansion of the boreal forest industry over the last few years, particularly in Alberta, has relied to a large degree on previously untapped extensive tracts of pure or predominantly aspen forest.

The aspen forest is not a climax stage in the boreal succession, and it owes its widespread occurrence to high fire return rates, the associated destruction of coniferous seed sources, and aspen's ability to regenerate vegetatively from surviving root systems. Relative to other boreal forest types and successional stages, aspen stands are productive, short-lived, easily regenerated, resistant to fire spread, rich in herbaceous and shrubby plants, and prone to disease and injury. Understanding these characteristics is key to the proper management of such forests.

Dempster, W.R.; Stevens, N.A. 1991. Aspen inventory and allowable cut. *In* S. Navratil and P.B. Chapman, editors. Aspen managment for the 21st century. Proceedings of a symposium held November 20-21, 1990, Edmonton, Alberta. For. Can., Northwest Reg., North. For. Cent. and Poplar Counc. Can., Edmonton, Alberta.

THE CURRENT INFORMATION BASE FOR CUT PLANNING

The current information base consists of forest cover and site classification; attribute sampling for volume, tree size, and quality; stand-level growth and yield models; harvest scheduling or forest estate models; and government legislation and guidelines.

Forest cover and site classification depend heavily on conventional photo interpretation and mapping techniques, which are sometimes modified to deal with particular challenges such as coniferous understory identification. Available techniques, including those for site-sensitivity assessment, ecological land classification, understory detection, and species differentiation, are cost-effective if users recognize that forest planning is a multistage sequential process. Information at the level of resolution required for short-term operational planning is not needed for all of the land base at the same time. Geographic information systems are increasingly being used to manipulate map and attribute data. The assessment of stand attributes, including volume, depends heavily on multiphase stratified random or systematic sampling techniques involving temporary or permanent sample plots and stem analysis. Growth projections are made using stand-level models. These generally have been simple, empirical volume-age curves or whole-stand models predicting volume as a function of age, site-index, and some measure of stocking or density. The output of these models, in the form of yield tables, is applied to aggregate wood supply models. These range from simple area-volume checks to linear programming models like Timber RAM or more operationally based simulation models like COMPLAN. In Alberta,

the forest act, timber management regulations, forest management agreements, operating ground rules, and timber management planning guidelines dictate or influence the calculation of harvest levels.

FACTORS INFLUENCING PLANNED HARVEST LEVELS

A logical assessment of information needs for aspen management depends on the goals of management and the factors influencing supply levels.

For the public owner of the resource, the goals of aspen management generally fall into the following categories:

- creation of wealth (typically viewed by provincial governments from a community accounting stance, with a high emphasis on employment and economic diversification);
- maintenance of benefits for future generations (sustainable development);
- the related concept of sustained timber yield, required by law in Alberta;
- full utilization and avoidance of timber waste (major objectives of Alberta and B.C. provincial governments in recent years);
- maintenance of soils site productivity;
- maintenance or enhancement of other resource values (water, wildlife, recreation, and range); and
- maintenance of genetic and ecosystem diversity.

Although most people would agree with these goals, it is probably an understatement to say that their translation into operationally definable objectives is a subject of some controversy and has not always occurred in a smooth and coherent manner. Given these goals, it is clear that harvest levels cannot be planned simply on the basis of existing inventories and that cuts will be significantly influenced by sustainability (and hence age class distributions, growth, and drain[1]), economics, and public policies regarding land use, conservation, and the environment. The following factors influence planned harvest levels:

- standing inventories (characterized in terms of volume, tree size, and wood quality);
- growth and drain (dependent on productivity, stocking, mortality, damage, and regeneration performance);
- forest age-class structure;
- economics (market price, production, and transportation costs); and
- land use and yield regulation policies.

PRIORITIZING KNOWLEDGE GAPS

Obviously, there are gaps in our knowledge of these influencing factors. Some knowledge gaps are inevitable, given the variability, risks, and uncertainty inherent in long-term biological and market systems. Foresters have a good understanding of inventory techniques applicable to aspen forests, however, and there is little excuse for failing to acquire the necessary information on standing inventories and age class distributions. We have a reasonable understanding of aspen growth and regeneration, thanks to the large body of research that has been accumulated on the subject. Our understanding of drain in aspen forests is poorer.

The most significant gap in our knowledge is not caused by our limited understanding of the individual factors influencing aspen management but of how these influences interact. In particular, conflicting interpretations of land use and regulatory goals and policies, and their impact on future forest conditions and wood flows, are poorly understood. This is illustrated by examination of the following statements, which represent the views of many people both inside and outside the forestry profession.

1. For sustained-yield management[2] we must restrict initial harvest levels to the long-run sustained-yield average[3] (LRSYA).

[1]Drain is loss in growing stock from any cause.
[2]Sustained-yield management is management of a forest property for continuous production with the aim of achieving, at the earliest practicable time, an approximate balance between net growth and harvest.
[3]Sustained-yield average is the level of cut representing the balance between growth and harvest in a forest having a perfectly regulated age class distribution, where all stands are harvested at the selected rotation age.

2. Harvesting of aspen in mature stands should be reduced from levels planned for existing tenures in order to preserve old growth.

3. Forest protection and more rigorous utilization will prevent massive growing stock losses.

4. Intensive management should be practiced to increase forest yields.

Are these statements true or false? Although there are no simple answers, work and experience in forest management areas and forest management units in northwest and west-central Alberta support the following facts.

1. Restriction of cut to LRSYA levels where mature growing-stock surpluses exist will delay the achievement of sustained-yield management objectives. Progress towards a balance between net growth and harvest will be delayed (as indicated by the persistence of an unregulated age-class distribution in Fig. 1), productivity and regeneration capacity will be reduced, and utilization benefits will be lost to society for all time (e.g., the potential harvest level above LRSYA indicated in Fig. 2). Harvest rates exceeding the LRSYA may be justified in such cases.

2. In forest management areas studied, accumulations of old aspen will increase over, and well past, the terms of present agreements and tenures (Fig. 3).

3. Massive utilization losses will result if aspen stands are not harvested before breakup[4] occurs.

   This is inevitable if harvest rates are constrained to LRSYA levels where managers are dealing with the type of age-class distribution shown in Figure 4. Note the volume-decline trends shown by temporary sample plots (Fig. 5) and remeasurements of permanent sample plots (Figs. 6 and 7). In addition to losses of usable timber, regeneration capacity of natural stocks will be reduced, and owners will have to choose between loss of productive land base or expensive rehabilitation costs.

4. Whereas aspen or hybrid poplar culture *may* be economically viable and socially beneficial on marginal agricultural lands close to mills, the widespread intensive cultivation of hardwoods on forest lands will undoubtedly create concerns regarding maintenance of genetic and ecosystem diversity. Any intensity of forest management that renders production costs noncompetitive cannot be considered sustainable development.

CONCLUDING REMARKS

Information gaps concerning the inventory, growth, and yield of aspen are for the most part being addressed, and the complexity of these processes is recognized.

Significant information gaps exist because of the complexity and outcomes of certain forest management choices and interrelationships. Not only foresters, but elected officials and the public increasingly involved in land-use decisions, must understand these relationships. The forestry profession has not been very successful in filling this information gap. Doing so may be our greatest challenge yet.

ACKNOWLEDGMENTS

The authors wish to thank those agencies who contributed data for this paper, particularly Daishowa Canada Company and Weyerhaeuser Canada.

[4]Breakup is defined here as the characteristic rapid decline in standing volume that results from the onset of disease and irregular mortality in mature aspen.

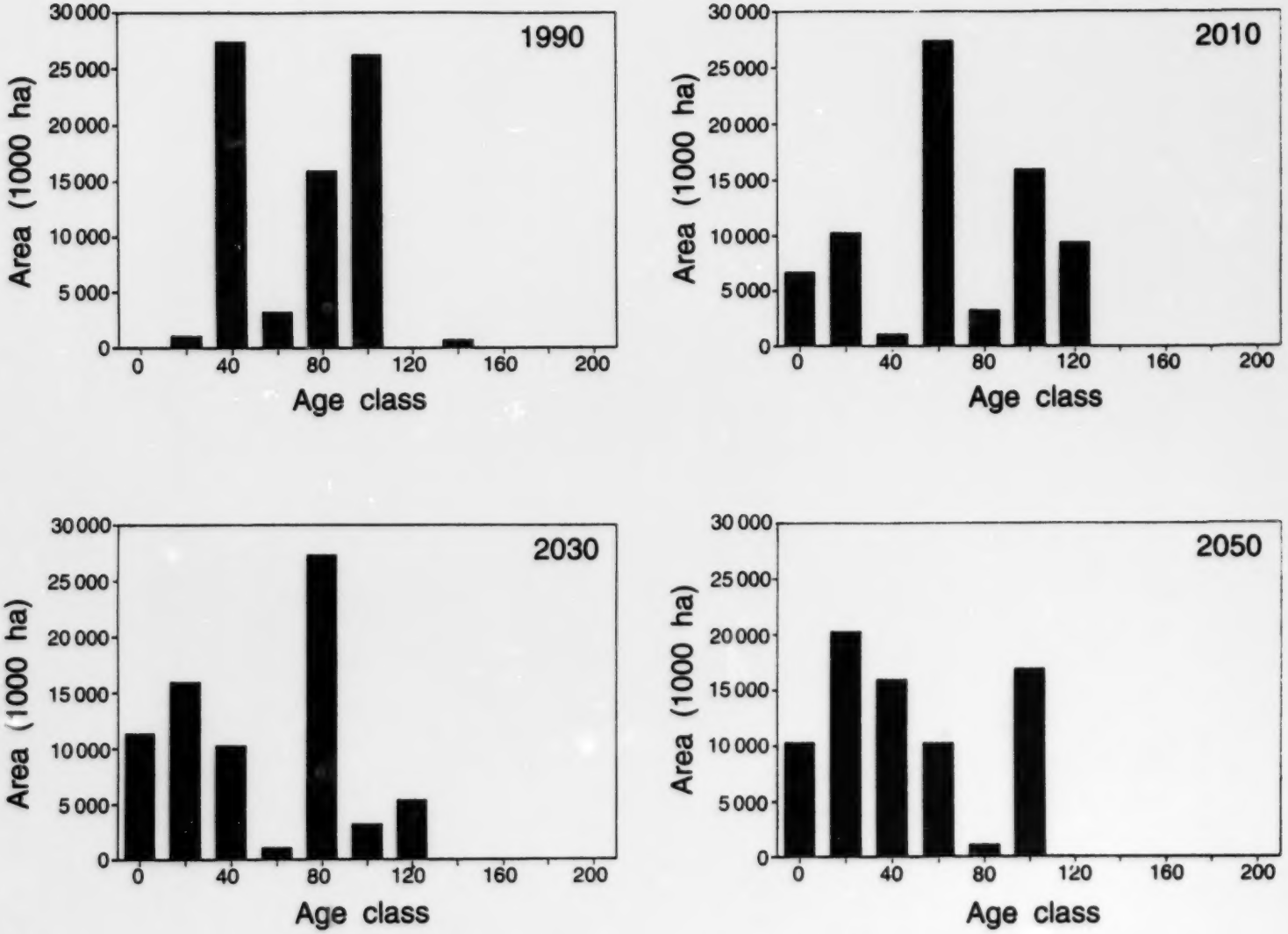

Figure 1. Age class distributions resulting from harvesting at the long-run sustained yield average.

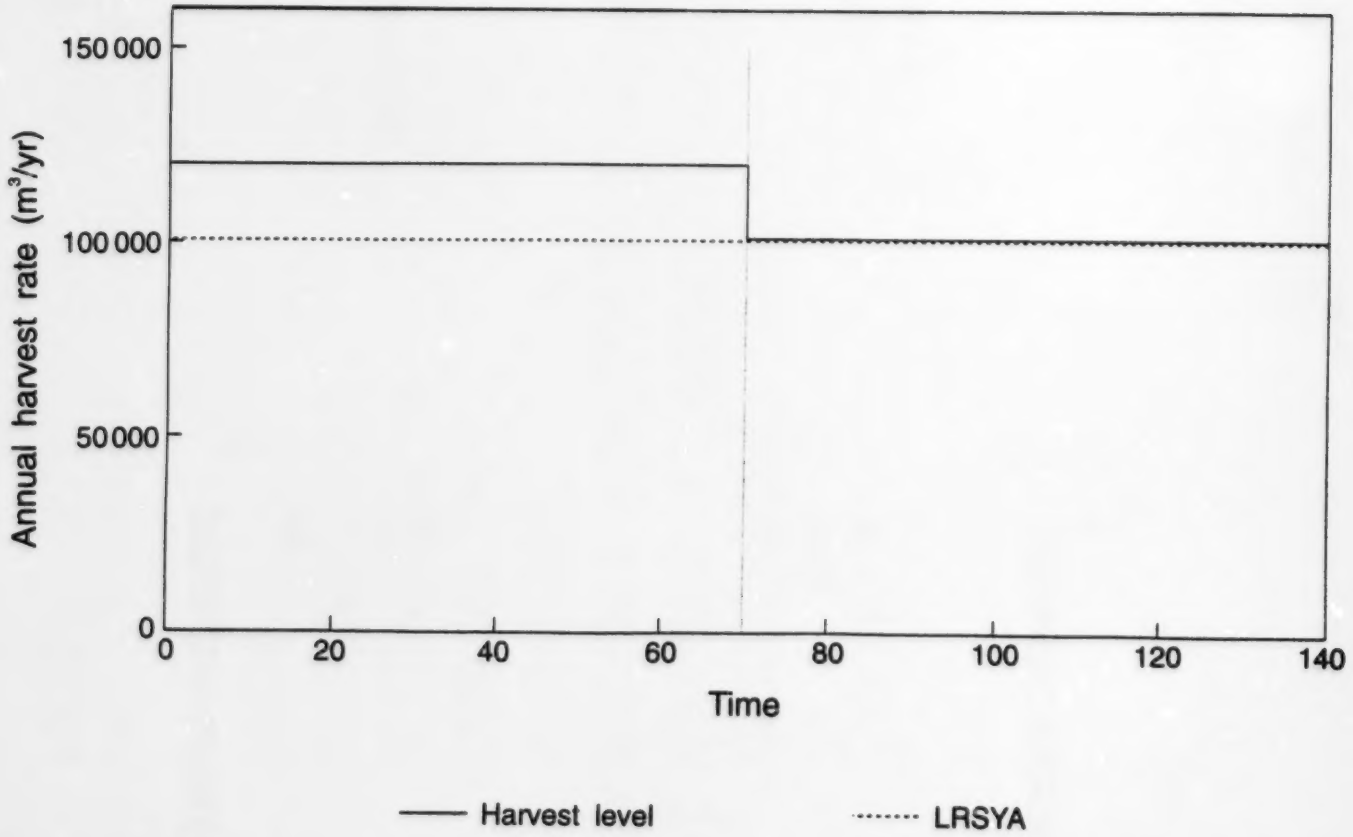

Figure 2. Harvest schedule based on harvesting at the even-flow cut level. (Illustrates volume losses resulting from constraining allowable cuts to the long-run sustained yield average).

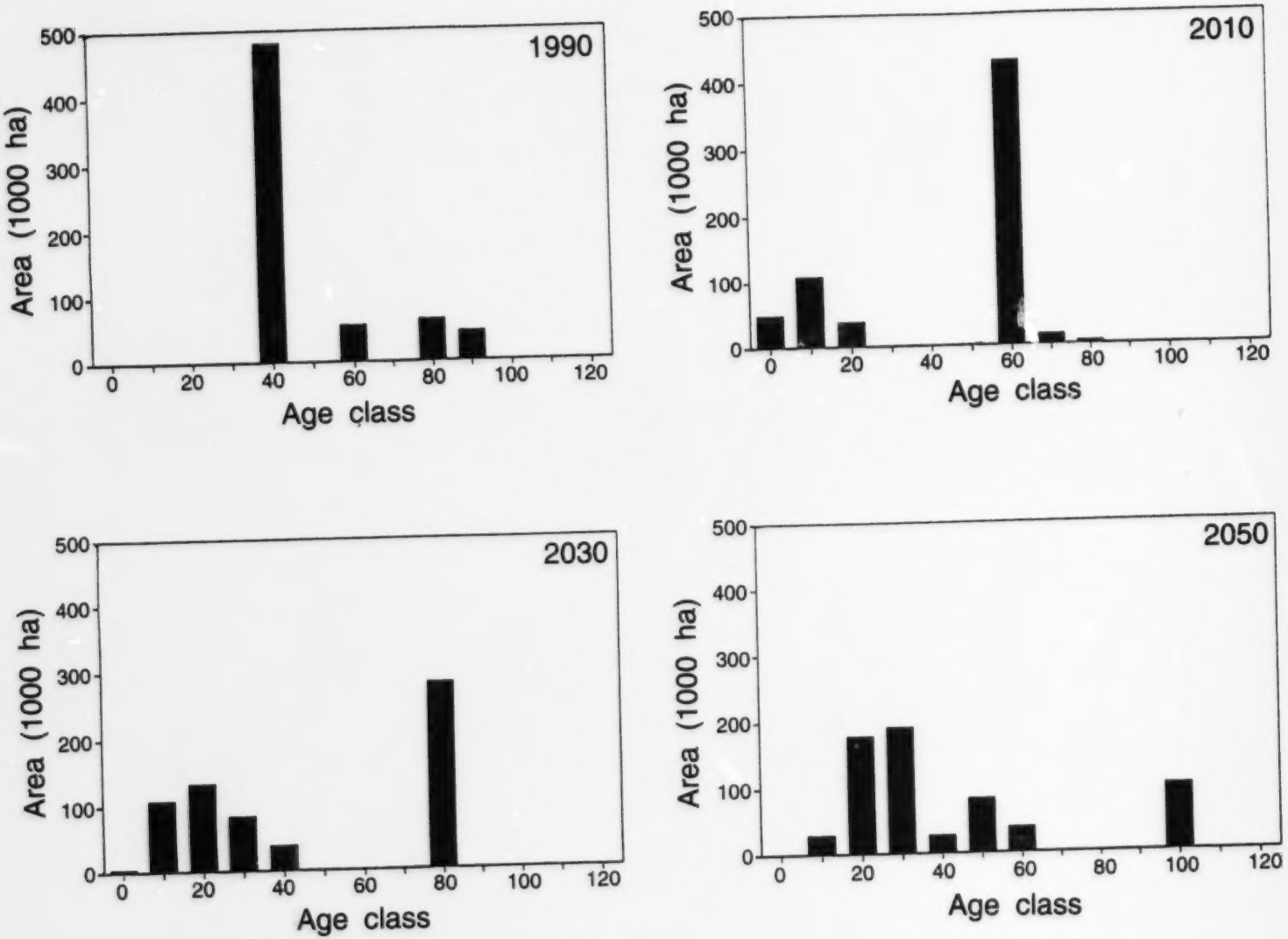

Figure 3. Projected age class distributions resulting from planned harvest levels.

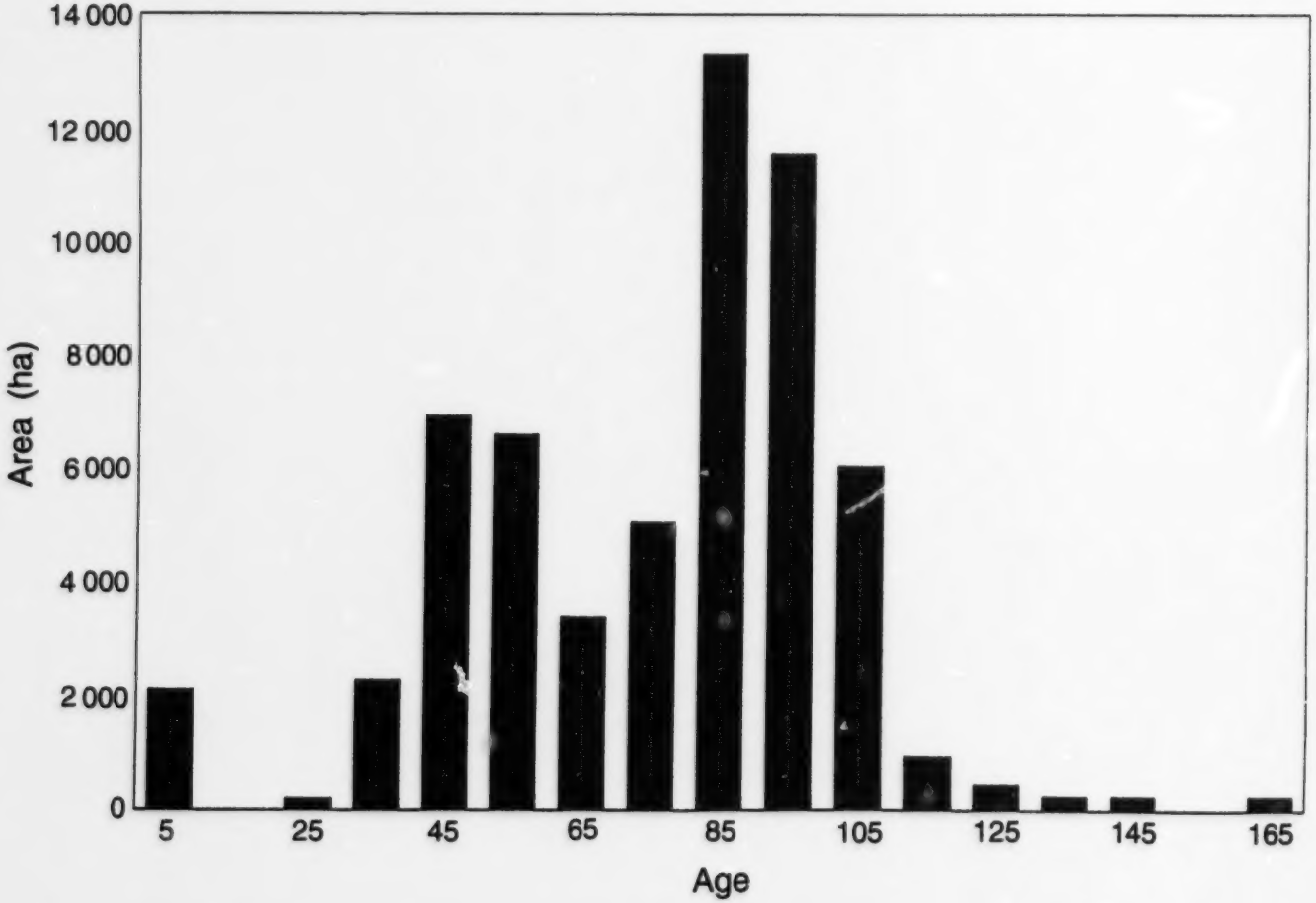

Figure 4. Present age-class distribution in an Alberta forest management area.

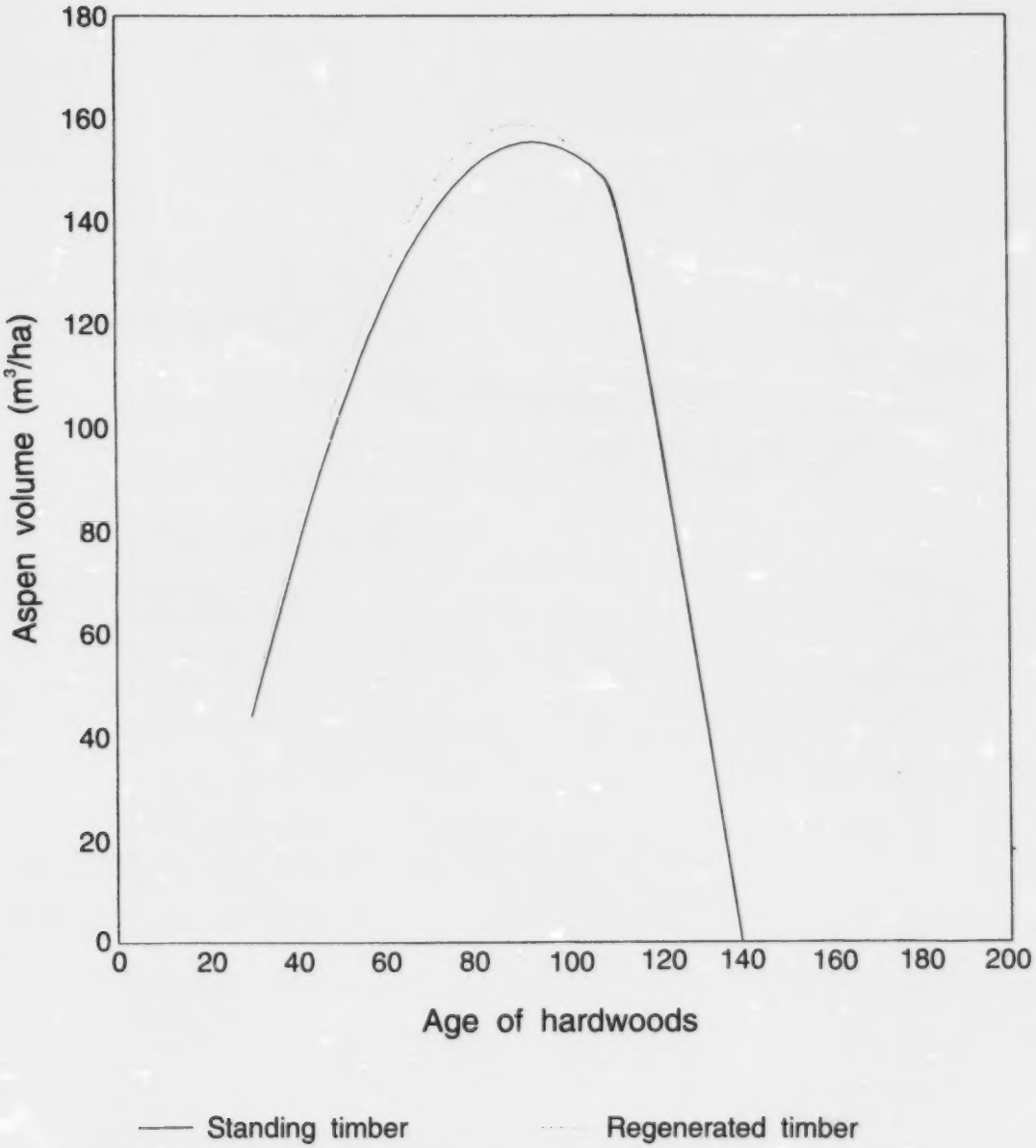

Figure 5. Volume-age trends in pure deciduous cover types based on analysis of temporary sample plot data.

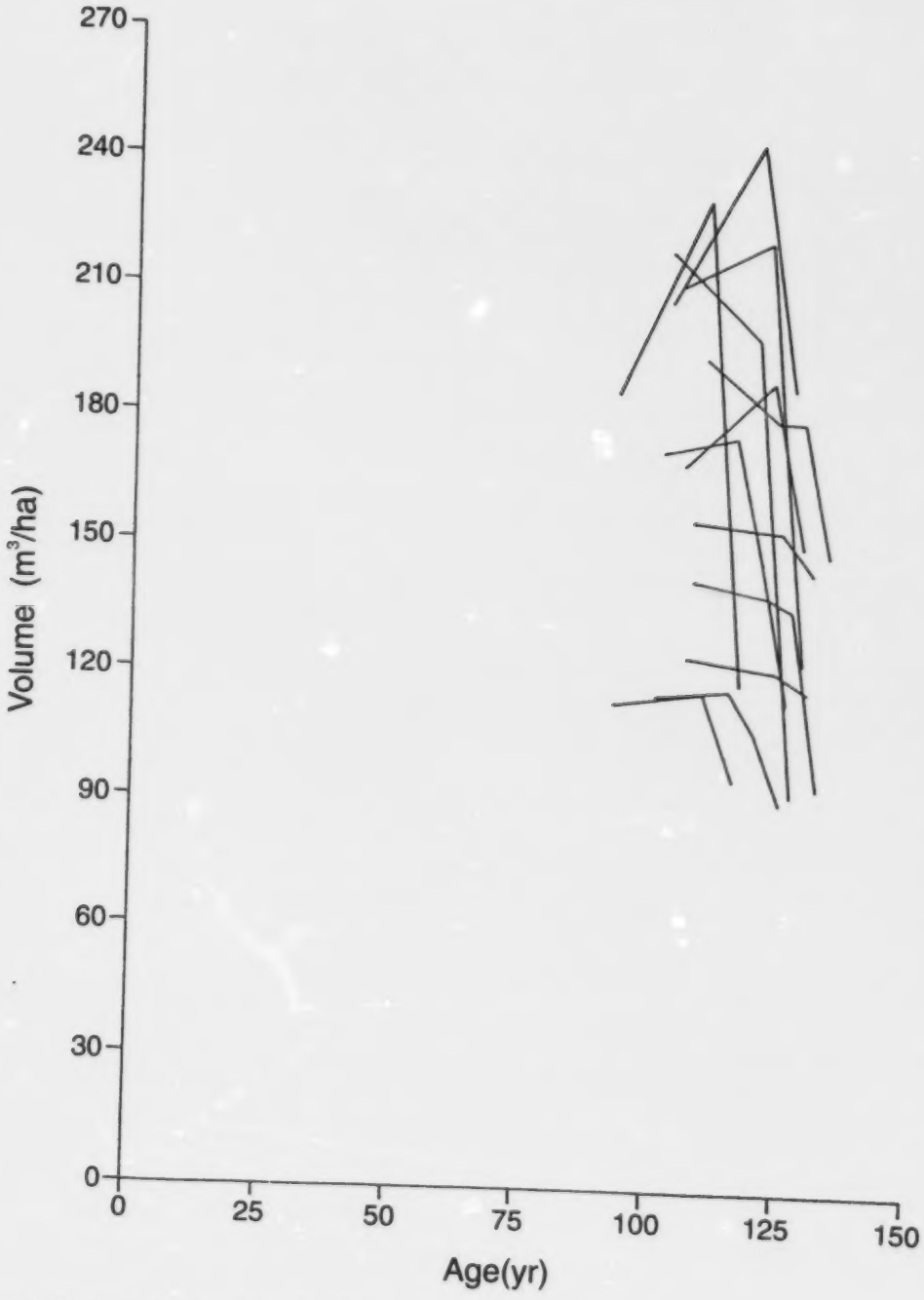

Figure 6. Volume age trends in deciduous permanent sample plots.

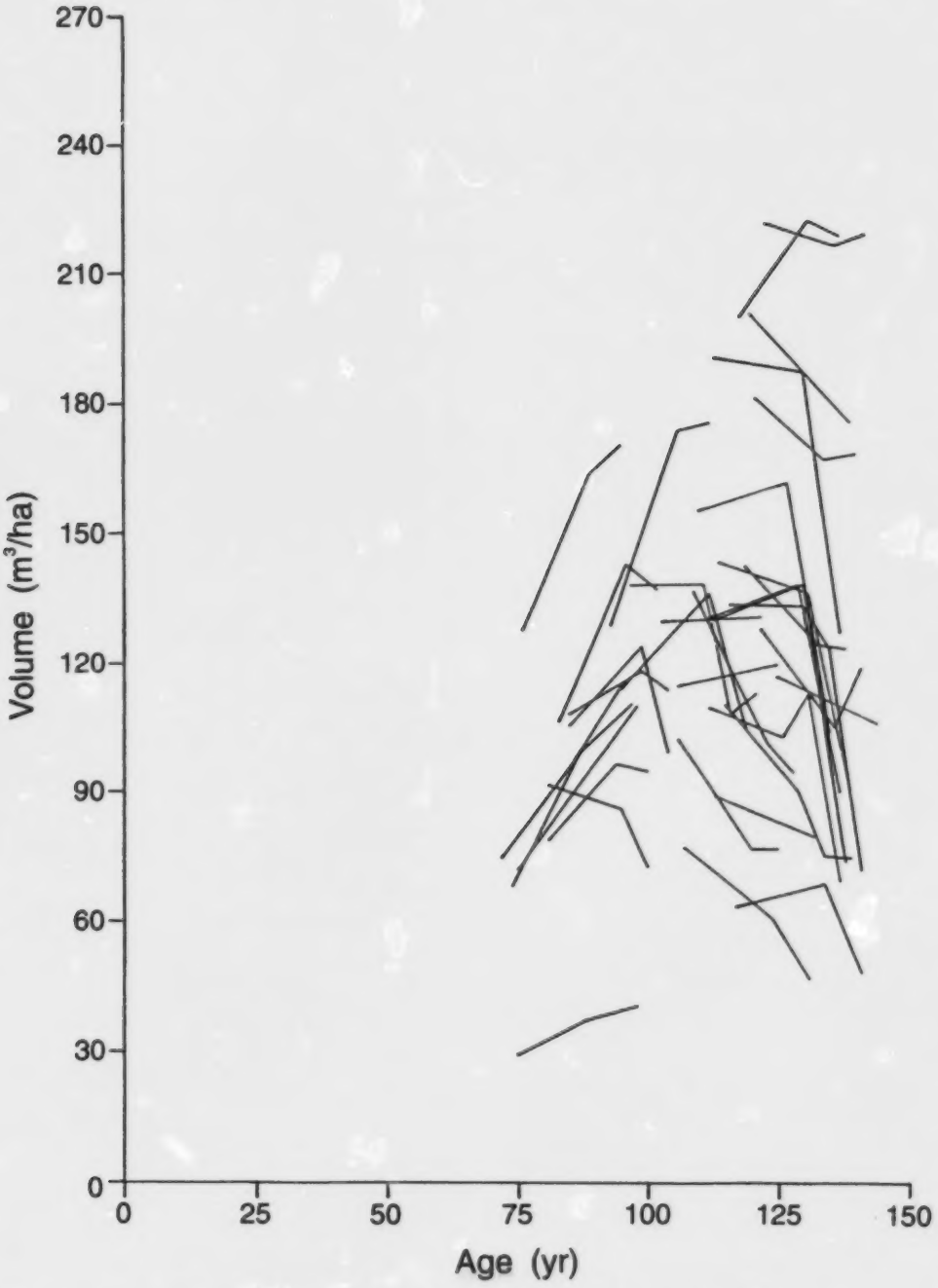

Figure 7. Volume age trends in mixedwood permanent sample plots.

MODELING GROWTH AND YIELD OF ASPEN IN WESTERN CANADA

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ABSTRACT

Using experimental plot data from numerous studies across the aspen growing regions of North America we developed a system of nonlinear equations describing annual changes of quadratic mean diameter and mortality in aspen stands. These relationships are the starting point for developing a growth and yield prediction system for this species. The system is based in Alberta. It allows for easy implementation of stand treatments such as thinning and fertilization, and is robust with respect to extrapolation beyond the data range.

INTRODUCTION

Less than a decade ago aspen was considered a weed tree in the vast boreal forests of western Canada. The recent dramatic rise in aspen harvest changed that and also increased the need for information related to the management of this species. Improved growth and yield prediction ranks high among tools and information urgently needed.

The main objective of the current study is to develop a comprehensive system of growth and yield prediction that would be applicable in western Canada for all major commercial tree species and cover types, including aspen. The system should be compatible with available forest inventory information and used for updating the inventory and calculating annual allowable cut. It should also be useful to evaluate growth and yield under a range of management scenarios and stand conditions. The model structure should be robust enough to allow its development from limited data and also allow reasonable extrapolation beyond.

Yield models currently used in the region do not meet the above objectives because they are based on cumulative functions with fixed yield trajectories and provide no allowance or adjustment for variations in stand density. Among the theories used as a basis of stand modeling, the self-thinning rule (Westoby 1984) seems to be the most suitable, being relatively simple and without major drawbacks. This theory states that in fully stocked stands mean plant size is a negative linear function of stand density, when both variables are in logarithms (Fig. 1). In other words, in such stands, density and radial growth are self-limiting. In open stands, the theory has to be complemented by a growth-survival model, derived from representative data, to simulate appropriate stand dynamics.

The self-thinning theory, or rule, has been applied for modeling growth and yield of various tree species growing in stands around the world, including lodgepole pine in Alberta[1]. In the latter case, the rule describes the relation between stand total volume, mean quadratic diameter, stand average height, and the number of trees per hectare.

Ciewzewski, C.J.; Bella, I.E.; Perala, D.A. 1991. Modeling growth and yield of aspen in western Canada. *In* S. Navratil and P.B. Chapman, editors. Aspen management for the 21st century. Proceedings of a symposium held November 20-21, 1990, Edmonton, Alberta. For. Can., Northwest Reg., North. For. Cent. and Poplar Counc. Can., Edmonton, Alberta.

[1]Cieszewski, C.J.; Bella, I.E. LPSIM—Lodgepole Pine Simulator for Alberta (in preparation).

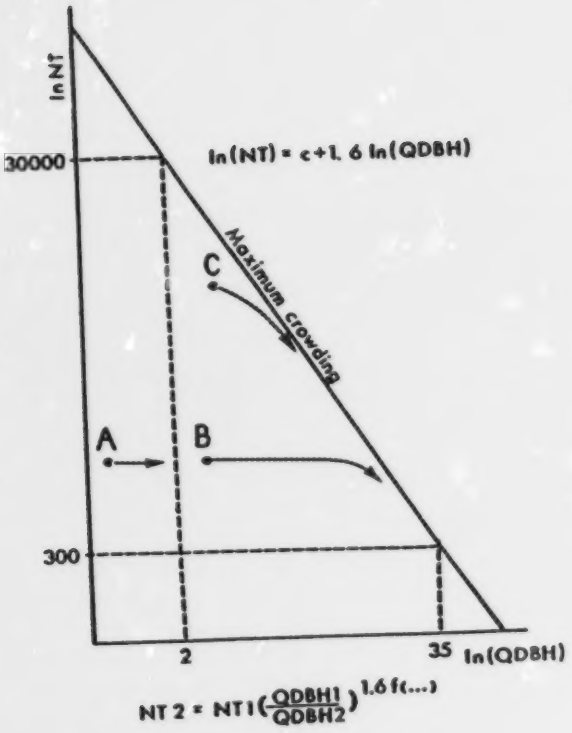

Figure 1. The self-thinning rule diagram.

In this paper we report on the development of a system of nonlinear equations describing annual changes of quadratic mean diameter and mortality in aspen stands to be used as a starting point for developing a growth and yield prediction system for this species. These equations are process-based advancements of empirical equations developed earlier from the same data base[2].

DATA AND METHODS

The experimental sample plot measurement data used in this analysis were obtained from numerous studies across the aspen growing region of North America and Europe (Table 1). Data consisted of 274 observation pairs, the bulk of which originated from the Lake States and prairie provinces (Table 2).

In line with the self-thinning rule, stand density, i.e., crowding, affects stand dynamics by reducing the trees' radial growth and causing mortality. One of the main challenges in formulating the basic model was to select a suitable density measure. This measure had to be expressed in such a way that it would be compatible with the self-thinning rule and would combine tree size and number of trees per hectare into a stand characteristic capable of quantifying stand density. We tried the following three measures of stand density based on the log-log relation between quadratic mean diameter and number of trees per hectare:

a) where the measure of density is the intercept, on the number of trees (Y) axis, of a line parallel to the limiting trajectory and passing through the analyzed stand density and diameter (Fig. 2a);
b) where the measure of density is the absolute vertical distance between the limiting trajectory and the point defined by the stand. That is, the difference between the logarithm of the maximum number of trees for the given diameter, defined by the limiting trajectory, and the logarithm of the actual number of trees in the stand (Fig. 2b); and
c) where the measure of density is the relative vertical distance, i.e., the ratio, between the maximum density, defined by the limiting trajectory for the actual stand diameter, and the actual number of trees in the stand (Fig. 2c).

In developing the lodgepole pine model we found that the best measure of the stand density was the third one, the relative vertical distance between the trajectory defined by the stand and the maximum trajectory. However, during the present analysis of the aspen data we found that for this species a better measure was the intercept value of trajectory for the stand in

[2]Perala, D.A.; Cieszewski, C.J. Generic growth and yield equations for trembling aspen (*Populus tremuloides* Michx.) based on the self-thinning rule (in review).

Table 1. Data sources

Author	Stand location	Cases	Variable and range		
			Site index (m @ 50 yr)	Age (year)	Dbh (cm)
Day 1958	Lower Michigan	3	18-24	10-25	3-11
Hubbard 1972	North central	6	27	7-24	3-14
Noreen 1986	Minnesota	6	24	4-20	1-10
Perala 1974	Minnesota	7	21	1-10	1-4
Perala 1978	Minnesota	48	23-25	13-53	4-31
Perala (on file)	Minnesota	19	24	15-39	5-17
Perala and Laidly 1989	Minnesota	24	25-31	5-21	3-13
Schlaegel 1971, 1972	Minnesota	62	18-24	10-62	5-35
Schlaegel and Ringold 1971	Minnesota	8	26	37-47	17-24
Pike 1953	Manitoba	3	17-18	35-55	8-16
Steneker 1974	Manitoba	52	16-21	11-44	3-23
Steneker 1969	Saskatchewan	21	19-21	14-30	4-15
Elfving 1986	Sweden	4	34	9-32	7-25
Vuokila 1977	Finland	11	22-23	11-48	3-25

Table 2. Summary statistics of data used for fitting diameter-density relationship for aspen using 274 observation pairs

Variable[a]	Mean	Standard deviation	Minimum	Maximum
Age 1	21.1	10.3	2	44
Age 2	32.2	14.5	3	62
QDBH1	9.53	5.251	0.55	22.21
QDBH2	15.03	7.504	0.88	34.75
Density 1	3348.5	7275.3	333	46085
Density 2	2173.9	3951.1	187	33853

[a]1 = first measurement; 2 = second measurement.

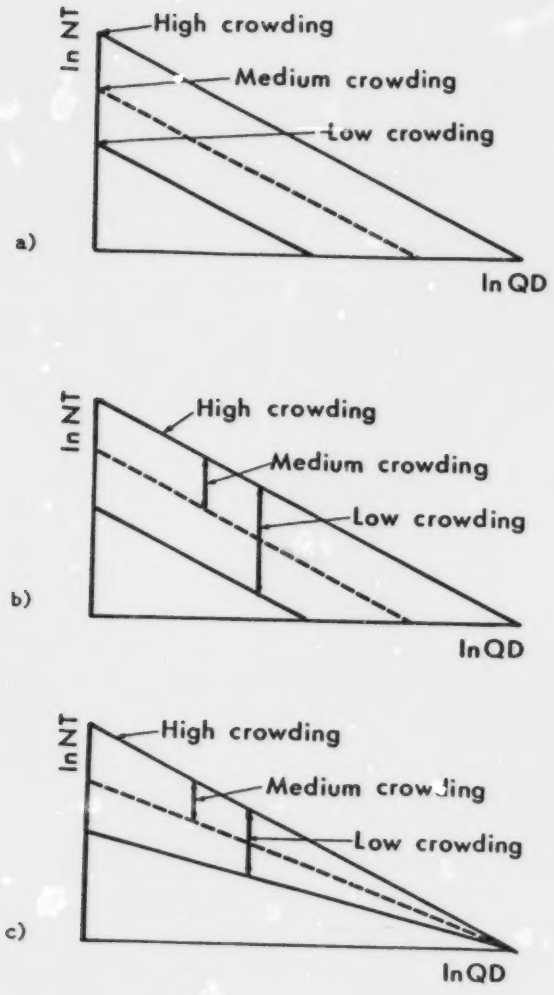

Figure 2. Three measures of density shown in terms of the self-thinning rule: a) intercept; b) absolute vertical distance from the limiting trajectory; c) relative vertical distance from the limiting trajectory.

question, i.e., the first density measure (a), which was then chosen for use.

MORTALITY MODEL DEVELOPMENT

As for lodgepole pine yield modeling, we started the mortality submodel development for aspen with a formulation of an equation describing annual mortality. We approached this using annual mortality or increments to achieve greater flexibility in modeling stand growth and to facilitate the consideration of different stand and environmental conditions. The required nonlinear relation was derived from the self-thinning rule ($\ln NT = c + 1.6 \times \ln QD$) and it defines mortality trajectories on the log-log diagram (Fig. 1). The relationship indicates high mortality near the maximum crowding line, and lesser or no mortality as stands approach open growing conditions. For example, in Figure 1, stands A and B represent open growing conditions with no mortality; stand C, near the maximum crowding line, represents high density and high mortality. The quantification of mortality from open to dense conditions is accomplished by a nonlinear function of the diameter ratio exponent (Fig. 3).

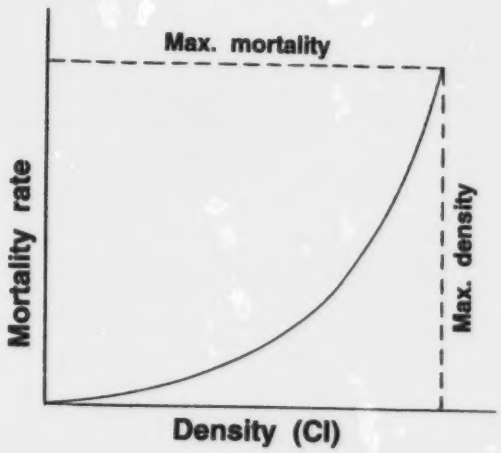

Figure 3. A function defining mortality rate, i.e., the slope on the log-log density diagram.

For our analysis, we had to express density changes on an annual basis. Our data of number of trees over age indicated an inverse exponential relationship (Fig. 4). In order to obtain annual mortality values, we did a logarithmic transformation on the data, which thus allowed a linear interpolation (Fig. 5).

In developing the mortality model we assumed that trees die from two basic causes: 1) crowding effects; and 2) other causes, which can be considered as constant, and related chiefly to insect, disease, mammal, and abiotic factors.

The crowding dependent, or variable mortality was represented by an asymptotic model adhering to the self-thinning rule; the constant mortality was modeled as an intercept and density independent. This means that a minimum mortality will occur even in open stands with no competition. After formulating the basic model structure we tested various hypotheses on the influence of age, site, and elevation on the two types of mortality.

DIAMETER GROWTH MODEL DEVELOPMENT

We started out with the relationship between quadratic mean diameter and a number of trees per hectare developed for lodgepole pine. Because our approach here is based on annual increment data, it was desirable to do the same for the diameter model. Therefore, the data had to be expressed and interpolated accordingly. We approximated mean annual quadratic diameter increments using linear interpolation, which was justified by the consistently linear trend of the mean quadratic diameter data (Fig. 6). For aspen, as for lodgepole pine, we used the differential form of the Von Bertalanffy growth model to describe annual increment of quadratic mean diameter (QD). This model essentially states that the increments are the differences between anabolic (photosynthesis) and catabolic (respiration) processes. The first is expressed as $n \times QD^m$ and the second as $k \times QD$; where n, m, and k are coefficients. In developing the model, our task was to meaningfully express these coefficients as functions of stand density and test their sensitivity to other variables.

CONCLUSIONS

A basic model structure was developed based on the self-thinning rule to describe aspen mortality and annual radial growth. The aspen growth and survival data used conformed well to the self-thinning rule[3] and demonstrated the rule's usefulness in growth and yield modeling of this species. As the model structure shows, only a portion of the mortality in the data is explained by the self-thinning rule and is independent of both density and radial growth. To complete a yield forecasting model for aspen stands, we now have the component mortality and diameter increment models; the height growth model that was developed in a separate study[3]; and we still need to develop a way to project the stand table over time. Then, with this information, stand yield can be estimated simply by using suitable standard volume tables.

[3]Cieszewski, C.J.; Bella, I.E. 1991. Height growth-site index equations for the major tree species in Alberta (in preparation).

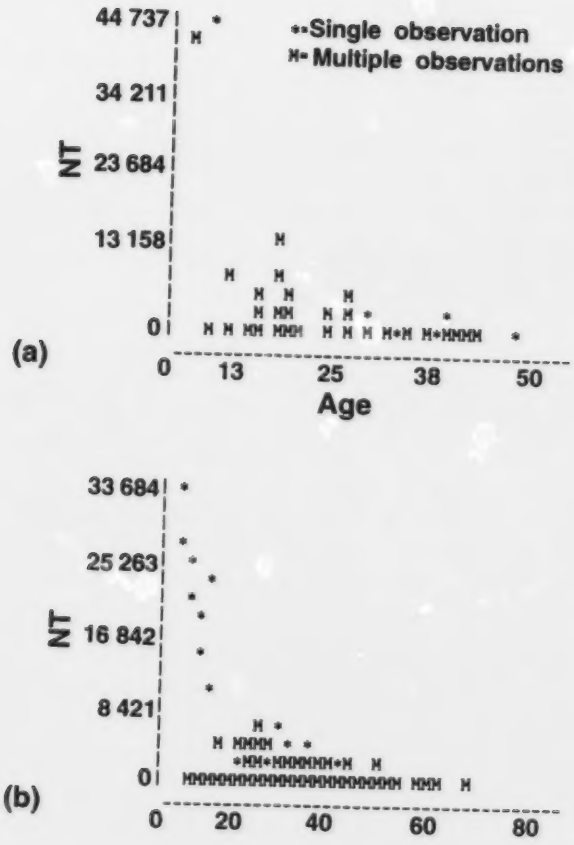

Figure 4. Number of trees per hectare over age (274 observations): (a) first measurement, (b) second measurement.

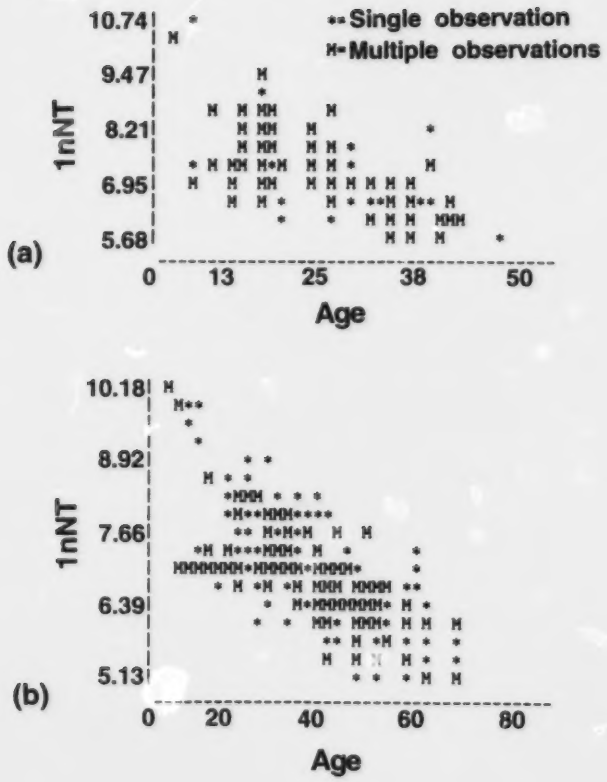

Figure 5. Logarithmically transformed number of trees per hectare over age (274 observations): (a) first measurement, (b) second measurement.

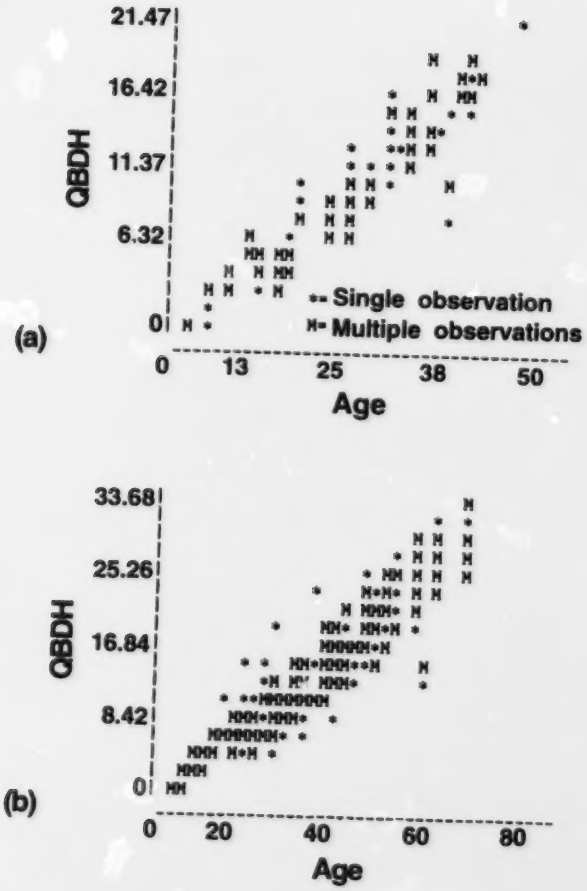

Figure 6. Quadratic mean diameter over age (274 observations): (a) first measurement, (b) second measurement.

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SESSION II

ASPEN MANAGEMENT AND HARVESTING

Moderator: B. MacDonald
Proctor & Gamble Cellulose
Grande Prairie, Alberta

ASPEN HARVESTING: A GOVERNMENT PERSPECTIVE

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ABSTRACT

One can look ahead to the future of aspen harvesting by examining the current logging situation in the Whitecourt Forest in west-central Alberta. In this forest, the 100% allocation of overlapping coniferous and deciduous annual allowable cuts has created a situation destined to be repeated throughout the province in coming years. Considerable ingenuity and innovation to adjust to unforeseen problems and limited information will be required by tomorrow's forest managers. Policy will continue to evolve.

INTRODUCTION

Aspen management for the 21st century! What a dynamic, forward-thinking approach to our aspen resource. One could speculate freely on what will happen in the next century. As an aspen manager, however, I for one am still grappling with aspen in *this* century. In my career as a manager we have gone from ignoring aspen, to eradicating it or converting it to grass, to cautious utilization, to impending scarcity—in less than a decade! Given this rapid transformation, it isn't surprising that aspen management policies have been scrambling to keep up. In many cases, management tools are deficient or lacking.

CURRENT LEVEL OF ASPEN COMMITMENT

Alberta produced 1 297 809 m^3 of aspen in 1988-89, of a total annual allowable cut (AAC) of 10 400 000 m^3, although by now we have allocated (total committed under tenure or pending final approval) around 8.5 million m^3 (approximately 81.4%). As we head into the 21st century we are approaching the complete allocation of the aspen resource, taking the industry into new harvesting regions and overlapping into large areas where the coniferous cut has already been heavily allocated. What will this mean?

In the Whitecourt Forest, this situation has existed for several years now. The coniferous cut of 2.2 million m^3 is completely allocated. Deciduous harvesting commenced in 1982 for oriented strand board (OSB), expanded in 1986 for OSB, expanded again in 1987 for pulp, and in 1989 increased yet again for use in newsprint. Of a total aspen AAC of 804 520 m^3, 738 635 m^3 has been already allocated, and the remaining balance is allocated to a second product line. In essence, Whitecourt has virtually complete allocation of all merchantable species timber volume, although actual production has yet to attain these values. In most management units every merchantable tree is spoken for—it actually or potentially belongs to someone.

The rest of Alberta is headed toward the 21st century, but the Whitecourt Forest is already there. In Whitecourt, the future is now!

ASPEN MANAGEMENT ISSUES AND CONSTRAINTS

The province has been mainly successful in promoting aspen harvesting. The mills are in place, licenses have been issued, harvesting and management plans have been approved, and the wood is being cut. In accomplishing these things, however, a number of new situations have been encountered, forcing staff to adjust "on the fly" in the following areas:

Darrah, D.W. 1991. Aspen harvesting: A government perspective. *In* S. Navratil and P.B. Chapman, editors. Aspen management for the 21st century. Proceedings of a symposium held November 20-21, 1990, Edmonton, Alberta. For. Can., Northwest Reg., North. For. Cent. and Poplar Counc. Can., Edmonton, Alberta.

1. Inventory
2. Maps
3. Cruising
4. Integration of operations
5. Utilization
6. Incidental conifer
7. Spruce understory protection
8. Reforestation

INVENTORY

The province's current Phase III timber inventory, although generally suitable for coniferous management planning, was completed while aspen was still considered a weed. Not a lot of detail was given to aspen stands, volumes, or ages. Consequently, aspen inventory information is currently unreliable and subject to great variation from predicted values.

Field staff have had to adjust to these limitations through local enhancement projects, detailed cruising (more about this later), and especially by more intensive review of company harvest plans by Alberta Forest Service (AFS) field foresters and technicians.

The decision-making process has therefore been shifted downstream, and harvest planning has become more subjective than objective.

MAPS

Phase III 1:15 000 cover type maps are the generally accepted operational planning base maps. They are suitably enhanced by cruising by both the AFS and private companies. As part of the original Phase III inventory, these maps suffer the same aspen shortcomings as the volume data. The accurate determination of aspen timber types, stand make-up, ages, or merchantability was a low priority. Consequently, these maps are inadequate to determine aspen separate from other deciduous species and are inadequate alone to determine land-base questions. They tell little about understories and are insufficient to predict age class or timber condition.

As in the case of inventory constraints, field staff have countered with increased cruising, surveys, and detailed harvest plan review via photography, aerial, and ground field review.

Again as in the case of inventory, this places more burden on professional and technical field staff "downstream" and makes the experience and competency of these people of paramount importance. Through subjective decisions made by these people, much of the province's aspen policy is being implemented.

CRUISING

Variable (prism) plot sampling (PPS) has been standard for coniferous licenses, done primarily for timber dues appraisal. Cruising methods were designed primarily for coniferous timber and hence are not always appropriate for aspen.

Aspen licenses are not appraised because all dues are at one provincial rate.

Aspen ages and heights are difficult to determine accurately.

Aspen cull is difficult if not impossible to estimate on the stump.

Aspen stem sizes may not be appropriate for the selected BAF Prism factors.

Greater aspen stand and stem variability requires more-intensive sampling to accurately estimate variables.

Field staff have increased the intensity of aspen cruising and presampling reconnaissance. They have switched methods from PPS to fixed area (6-m radius) or strip (2-m) cruising to attempt to gain increased coverage or a more representative sample. Industry cruises as well.

Interior cull is still not adequately addressed and is largely ignored. A regression formula based on tree size appears to have some promise and is being investigated at this time.

INTEGRATION OF OPERATIONS

As stated earlier, overlapping allocations of coniferous and deciduous timber, especially

where different companies are involved, creates the need to integrate harvest plans for both species. Because the companies each have their own management plans and cutting sequences which have not been meshed, the first company in a given area must not only plan harvesting for its timber but must also incorporate harvest plans for the alternate species into one integrated harvest plan. This plan is referred to the alternate company for general approval. The secondary species blocks can either be harvested by the first company and the wood sold or traded to the second, or the blocks simply left for a second-pass removal.

In its extremity, integration of harvest plans includes pure coniferous cut blocks, pure deciduous blocks, and mixedwood blocks. This includes alternating first and second cuts of all species, road use and reclamation agreements, log exchanges, coordination of timber flow, determination of land base and timber dues, as well as reforestation responsibility. The process can be both frustrating and tortuous, although thankfully in most cases we are able to come to some resolve with industry.

UTILIZATION

Aspen, of course, has traditionally been left behind on mixedwood cut blocks and either ignored or subsequently destroyed during silvicultural treatment.

With the advent of overlapping deciduous cutting rights, we could be faced with the possibility of harvesting pure aspen on one side of the road while cats are smashing and piling mixedwood aspen residual on the other. To prevent this, the AFS has required from the beginning that all aspen residual be utilized before it approves pure aspen harvest, even when there are two companies involved. This has not always been easy due to intercompany negotiating tactics, but by preventing pure aspen harvest as well as any reforestation of the mixedwood block until all aspen is removed, we have achieved substantial success in this area.

As much as possible, the AFS promotes one-pass removal of both species for efficient utilization. Two-pass removal is also accepted providing it is timely (within 2 years of initial harvest). This reduces aspen fiber losses to wind, drying, and decay.

There remains a fast-disappearing attitude that aspen is a low-value weed species whose salvage and total utilization should not be pushed—until recently it was (and occasionally still is) piled and burned. Fortunately, with impending shortages, this attitude is much less prevalent. With multiple aspen users and purchasers, a highly competitive situation is developing for aspen salvage. This bodes well for total utilization in future.

INCIDENTAL CONIFER

Few aspen stands are absolutely pure. A large number contain some conifers scattered throughout the canopy. By definition, coniferous volumes in a "pure" aspen stand must be less than 50 m^3/ha and must be labelled *incidental conifer*—mainly spruce but some pine as well.

There has been considerable attention paid to the allocation of this wood, as interests compete for ownership.

Incidental coniferous volumes have not been inventoried, so volumes are not known precisely, no formal allocations have been made, and the volume is considered nonsustainable because coniferous reforestation will not be done in aspen cutovers.

Field staff have used discretion in managing these volumes. Where volumes are light and no local demand for the wood exists, the aspen operator has been allowed to take it. Where local demand is great, however, the wood is left standing, for follow-up second-pass removal, usually by Miscellaneous Timber Use (MTU) operators with a local timber permit or commercial timber permit.

Within coniferous Forest Management Agreements (FMA), this wood belongs to the FMA holder, and formal arrangements with that company must be made for its harvest and use.

A large aspen operator will generate several thousands or even tens of thousands of cubic metres of high quality (very large) incidental conifer. Disputes over allocation of this wood

have been carried to the highest levels of AFS management and on occasion into the political arena, as well. Look for these conflicts to become more widespread in future.

SPRUCE UNDERSTORY PROTECTION

Following natural succession, aspen gives way over 60-100 years to later seral vegetation stages, usually spruce. Accordingly, very many mature aspen stands have a significant understory of spruce regeneration. Current provincial policy requires protection of this understory during aspen logging, where spruce regeneration densities exceed 250 stems/ha. This has not been easily accomplished, as the concept is new, costs and benefits are inequitably distributed, and reliable and effective techniques are still being researched.

A FERIC coordinated study dealing with methods and costs is now partially completed. A Forestry Canada long-term plot monitoring program is underway and will better identify impacts on the protected spruce seedlings.

This study notwithstanding, field staff have required protection measures applied by aspen harvesters as a condition of approval of harvesting plans. So far, low-intensity low-cost measures have been required to accomplish *some* level of protection with predictably mixed results. Several excellent successes have been achieved along with numerous failures.

With no protection emphasis, the spruce understory is totally eliminated; with moderate protection measures the understory can be reasonably protected (100-250 stems/ha); and with heavy protection it is possible to protect spruce regeneration to density levels approaching full stocking (500-800 stems/ha).

Understory protection issues have spread through central and northern forests over the last couple of years and will continue to spark considerable debate during the remaining years of this century. Maybe by the next century we will have sufficient knowledge, skills, and policies in place to deal with this issue.

REFORESTATION

Regeneration of aspen should be easily accomplished, but some problems are likely and indeed have already appeared. While aspen blocks usually resucker prolifically, roads and some landings compacted and cleared to C horizons do not adequately regenerate, and seedling growth rates are substantially reduced. Between 15% and 25% of the aspen block areas are thus affected, and the problem has been especially acute in processed (shortwood) operations. Space needed for slashing equipment and redecking has required double roading. (Recent modification to decking and slashing has reduced this requirement to single roading this last summer.)

Aspen regeneration has been a government responsibility pending recent changes in regulations, and the AFS, working with industry, has dealt with the road problem through decompaction (ripping, subsoiling), roll-back, and coniferous seeding or planting.

Because we are entering the 7th year from the first aspen harvest, and regeneration surveys are required, the AFS and industry are in the process of selecting a survey method (photos, aerial, ground), and dealing with reclamation and regeneration of nonstocked areas.

There may also be local restocking problems under dense balsam poplar residual and growth problems resulting from compacted soils in summer logged blocks. These require further assessment.

In future, aspen regeneration issues will become more operational. Planting aspen seedlings, triploid or exotic stock, or possibly introducing coniferous planting into the aspen land base will become more frequent.

In areas of overlapping coniferous or mixedwood quotas with pure aspen cutting, the possibility of land base swaps of aspen with coniferous areas will undoubtedly be discussed and perhaps implemented on a small scale (with due consideration for AACs).

SUMMARY AND CONCLUSIONS

It is apparent that there are many problematic "gray areas" in aspen harvesting; however, today's problems are tomorrow's solutions. As the 21st century nears, look for most of these problems to be resolved and for standard policies to be in place throughout the province. Better data, especially inventory and maps, are essential if appropriate aspen management is to be conducted. Cruising procedures must be tightened. Accurate aspen cull estimation methods must be available in the field. Integration of operations will be more difficult but will be a standard requirement. Utilization will continue to improve and will very soon attain coniferous levels. Disputes and demands for incidental conifer will increase greatly. Spruce understory protection will "come of age," and standards and policies will be better defined. Aspen reforestation will not always be easy and cheap.

Although progress is being made, new questions and issues are beginning to emerge: What about balsam poplar? Where is our birch? How do we integrate conifer layout with pure aspen, with mixedwood stands, with balsam poplar, with birch .....?

The 21st century will have challenges of its own.

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ASPEN HARVESTING: AN INDUSTRY PERSPECTIVE

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ABSTRACT

Aspen harvesting in Alberta in the past was just that, harvesting. Daishowa Canada, however, started to utilize balsam poplar, black poplar, and birch in 1989. This will change how hardwood species are managed in Alberta. The problems associated with harvesting mixedwood boreal forests will continue to force managers to come up with solutions regarding quality, coniferous understory protection, development of economical harvest systems, and regeneration of the site when managing hardwoods.

INTRODUCTION

I am pleased that I was invited to talk to you today to discuss an industry perspective on aspen harvesting.

There have been several symposiums on aspen management in the past 5 years or so. I have always had a complaint about these symposiums. Everyone identified the problems associated with such things as mixedwood management, aspen cull factors, and re-establishing conifers on a site following harvesting, but seldom were any solutions offered.

It is now my turn to disappoint myself, as I do not have many solutions, either. I can, however, relate to you our problems and offer some things that we are doing in Peace River to deal with the harvesting of hardwood species.

Thorp, W. 1991. Aspen harvesting: An industry perspective. *In* S. Navratil and P.B. Chapman, editors. Aspen management for the 21st century. Proceedings of a symposium held November 20-21, 1990, Edmonton, Alberta. For. Can., Northwest Reg., North. For. Cent. and Poplar Counc. Can., Edmonton, Alberta.

First, let me tell you a little about my background. I spent some 10 years figuring out how to destroy poplar to establish conifers. I did this using various combinations of extensive site preparation and herbicides. I have had as many degrees of successes and failures as I have used combinations of treatment.

Feeling that I had conquered the hardwood species, I then took the easy way out before someone proved me wrong. I became a hardwood forester for an oriented strandboard plant in Dawson Creek, B.C., and I subsequently joined Daishowa in August 1988.

At Daishowa I am now faced with managing hardwoods, mixedwood stands, and conifers for a kraft pulp mill in northern Alberta. Needless to say, we do not have all the solutions to the problems; however, one management problem was solved when hardwoods became a valuable species. The old system of pure conifer management in northern boreal forests was doomed to fail no matter what previous conifer managers thought. This is particularly true now that continued herbicide use is becoming more questionable each day.

I was asked to speak today on aspen harvesting. I am pleased to say that Daishowa feels it can expand that into hardwood harvesting through the utilization of aspen (*Populus tremuloides* Michx.), poplar (*Populus trichocarpa* Torr. and Gray and *Populus balsamifera* L.) and paper birch (*Betula papyrifera* Marsh.). My personal feeling is that full utilization drives good management, and underutilization drives or at least allows poor management. Full utilization will force managers to find solutions to many past problems.

The harvesting of these species, done in tree length form, does not require any special techniques or equipment other than conventional

logging equipment. In fact, hardwood harvesting has seen some old tree snippers come out of retirement. Grapple and cable skidders are used along with power saws or stroke type delimbers for delimbing. Loading is generally done with either front-end loaders or button top loaders at roadside.

In my opinion, the most efficient and safe way to harvest hardwood is using modern feller bunchers, grapple skidders, and stroke type delimbers followed by button top loaders at roadside.

Feller bunchers can work at their own speed through the blocks, far enough ahead that a breakdown does not effect the skidding. (Peace River does not normally get that much snowfall, so burying of logs is not a problem.) The use of a roadside skidding system reduces the average skid distance, thereby maximizing the efficiency of the skidder.

The roads are placed strategically so that an entire block can be skidded before any wood is trucked out. Traditionally, landings required the logs to be loaded out no later than a day following skidding. If the loader broke down or if the trucking phase was not possible because of wet weather or late freeze-up, skidding would stop until the landings were empty.

Delimbing is generally easier for hardwoods because the lower bole of the tree does not have many limbs. Delimbing also does not have to rely on the other phases of logging; skidding is complete provided it is sized, planned, and completed ahead of the loader.

The loader can come in at any time following these operations without being affected by the other operations. Each component can therefore be run at its maximum efficiency. This system eliminates the bottlenecks associated with other types of harvesting. This phase logging system may also require more active cut blocks than normal because each phase operates independently of the others.

This system of logging requires a high capital investment. High capital investment requires higher volumes to amortize against; otherwise, costs per unit of wood increases. The most efficient volumes seem to be 100 000-120 000 m^3 for the winter months at 24 hours a day, at least 6 days a week. We also intend to provide for summer employment of this equipment to help reduce unit cost.

Daishowa intends to harvest on a 9-month basis but to haul on approximately a 6-month basis. Hardwoods can be harvested during summer months in our area because they generally occur on well-drained sites; this eliminates or at least reduces the trafficability and rutting concerns associated with coniferous harvesting. Another advantage of this system is that we can reduce the need for extensive all-weather roads, and we haul less moisture and more actual wood content by curing in the summer. The other reason for not hauling as much in the summer months is that we gain approximately 30% pay load by weight for the trucks with increased axle weight allowances in winter months.

The physical job of harvesting is therefore relatively straightforward; however, we are faced with the other well-known problems, which I will discuss briefly. These problems are mixedwood management, cull factors associated with hardwoods, and integration of operations with conifer operators.

MIXEDWOOD MANAGEMENT

As I mentioned earlier, managing stands as if they are purely coniferous is doomed to fail in the northern boreal forest. By default, coniferous priority management will undoubtedly become mixedwood management. The coniferous management objective must therefore be to keep hardwoods at a tolerable level so that coniferous yields will be acceptable, rather than trying to eliminate hardwoods altogether. The other aspect of this is that many areas of so-called pure deciduous stands contain coniferous understory. I see these stands offsetting any future loss of yield caused by hardwood competition on coniferous land bases. We are now carrying out operational field trials on understory protection. We first flew and ground checked the areas where we were going to harvest to determine whether there would be sufficient understory to warrant protection.

Once that was confirmed, color infrared leaf-off photography was carried out to stratify the

understory stands into low, moderate, or high density. A map showing the layout of skid trails was prepared, and the overstory was harvested. Monitoring of the results will come later.

The problem in dealing with this is that many of the new tenures such as Daishowa's Forest Management Agreements (FMAs) have two or even three managers on the same land base. Therein lies another problem of how it will be managed on a coordinated basis. There should also be incentives put in place for the deciduous operators to protect understories that another party benefits from. So the question is not one of will we have mixedwood stands in the future but one of who manages what and what is the anticipated yield on each land base for each species. The preliminary results of our trial are as follows:

1) there will be significant increases in costs as a result of reduced logging productivity;
2) the methods proved what is possible, but perhaps not feasible;
3) additional costs might be easier to justify if the same manager looked after both species; and
4) a deciduous operator might even recommend that the spruce be eliminated to maximize the deciduous yield. This is a rather radical approach, but not unlike mother nature's use of fire in the past.

Growth and yield studies and cooperatives on research in understory stands are underway to determine the potential yield of the future stand, the species composition, and to what rotation they should be managed. We are working on this and hope over time to be able to quantitatively answer these concerns.

CULL FACTORS

As any hardwood manager will tell you, a primary concern is the cull factor caused by decay in hardwoods. It is difficult to recognize decay in hardwoods particularly during winter months in our peak logging season when over half of the work is done in darkness. How do we propose, then, to deal with the cull factor?

We hired a consultant to carry out an extensive feasibility study, which included destructive sampling of some 1000 trees from selected stands to determine average cull factors by stand type. Daishowa decided to use 50% visible butt rot as the upper limit for utilization (obviously we may have to adjust this as we develop better information). In our first year of operation, it appears that the average cull from pure hardwood stands will be close to the feasibility study. However, as I will discuss a little later, deciduous trees harvested in integrated operations are generally older than pure deciduous stands and past our projected rotation ages.

Loggers are encouraged with penalties through a strict quality control program to deal with what we call "avoidable cull" such as excessive crook, broken tops or butts, pistol grips, and visible butt rot to reduce processing problems. We can only penalize the loggers for what we consider to be avoidable decay.

The other problem we had in our first year of operation was what conversion factor to use to pay our loggers. We had conversion factors all over the map, from a low of 950 kg/m^3 to a high of 1350 kg/m^3 of usable wood. You can appreciate the problem a logger would have in determining his pay and the problems we had in ensuring we were consistent in paying contractors.

We therefore selected to pay by the metric tonne, rather than volume, for the time being and penalize for the avoidable cull. This may be adjusted once we have a better handle on localized information by the stand type harvested. Because we pay by the tonne we achieve maximum advantage by maximizing winter hauling and researching into "sour felling" (decking in the bush all summer and hauling in the winter).

INTEGRATION OF OPERATIONS

In the past, coniferous operators fought with the hardwood component when harvesting and reforesting. Now, with the full integration of both coniferous and deciduous, the whole resource gets utilized, and subsequent site preparation is easier because the hardwood trees are not a physical barrier.

We are also working towards full integration at the planning stages, whereby we will ensure isolated patches of coniferous or deciduous trees will be utilized on a one-entry basis, reducing the impact of reopening areas.

Cost sharing of roads based on a percentage of the volume used will be done to reduce costs for both operations.

We must continue to be innovative in solving the problems associated with the boreal forests and remain completely flexible both from a policy and operational perspective.

As a deciduous operator, Daishowa is excited about the future prospects of utilizing this past "weed" species. We must keep in mind, however, that our end product is generally of less value, and we must therefore be innovative to remain competitive. As a final statement, it is my belief that utilization of this resource will ensure that these problems will be overcome, provided everyone is reasonable.

THE IMPACT OF ASPEN HARVESTING ON SITE PRODUCTIVITY

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ABSTRACT

Aspen management can affect site productivity in two major ways: First, aspen accumulates large amounts of nutrients (especially Ca) in its biomass. Harvesting removes these nutrients from the site and, in the long run, site quality will decline if these nutrients are not replenished. Second, the harvesting operation itself can cause site quality loss through soil physical disturbance or through accelerated soil organic matter decomposition and nutrient leaching losses. Our understanding of the processes controlling site productivity is very weak, therefore our ability to predict the consequences of management activities on site productivity is very limited. Current research will help correct this weakness.

INTRODUCTION

Land managers have long been concerned with the effects of management practices on site productivity. As the potential for site damage has increased through the use of heavy equipment, shortened rotations, and more complete tree utilization, this concern has increased and spread to other groups. The possible negative impact of intensified timber harvesting on sustained production from forest lands has been the focus of several recent symposia (Ballard and Gessel 1983; Dyck and Mees 1989; Gessel et al. 1990). These symposia summarize the current state of knowledge, give management direction based on that knowledge, and make suggestions concerning needed research.

Trembling aspen (*Populus tremuloides* Michx.) is the most widely distributed tree in North America (Perala 1991), and in a few decades it has been transformed from a weed tree to an important commercial species over much of its range. Its commercial importance will likely continue to grow. Aspen is short-lived; its mean annual increment culminates at about 30 to 40 years in the east and up to twice that long in the west. Aspen usually occurs in even-aged stands with relatively uniform tree sizes, making intense harvesting systems with heavy machinery and full tree utilization possible.

The objective of this paper is to review the possible site productivity implications of aspen harvesting with emphasis on the soil factors most likely to influence plant growth.

SITE PRODUCTIVITY

Site productivity can be defined in terms such as plant biomass, wildlife, water, and aesthetics. For this paper, site productivity refers to the inherent ability of a site to grow vegetation. This is largely determined by soil and climatic factors. The best measure of site productivity is net primary production (Grier et al. 1989). Stand productivity, the actual production of a given stand, is controlled by inherent site productivity and by insect, disease, thinning, fertilization, and other factors. Site and stand productivity are not necessarily related; to distinguish between them is crucial in evaluating management activities. For example, severe scalping may improve survival and growth of planted trees by controlling the competing vegetation. In such a case, stand productivity might be enhanced but site productivity diminished. Management practices affect site productivity primarily through their effects on the soil, and it is by soil monitoring that the implications of management practices on long-term site productivity can best be evaluated.

Alban, D.H. 1991. The impact of aspen harvesting on site productivity. *In* S. Navratil and P.B. Chapman, editors. Aspen management for the 21st century. Proceedings of a symposium held November 20-21, 1990, Edmonton, Alberta. For. Can., Northwest Reg., North. For. Cent. and Poplar Counc. Can., Edmonton, Alberta.

HARVESTING IMPACTS

Forest harvesting can affect site productivity in two major ways. First, it takes with it organic matter and nutrients in the harvested biomass. These materials have accumulated over the life of the stand and may have caused slow soil changes over time. Secondly, it directly affects the soil, for example, by accelerated leaching of nutrients, increased oxidation of soil organic matter, and physical disturbance of the site, i.e., soil displacement, erosion, or compaction.

Monitoring soil properties will help evaluate management practices, but for deeper understanding, extrapolating to new situations, and designing ameliorative treatments, the actual processes controlling site productivity, such as moisture and nutrient dynamics, must be quantified.

Biomass Removal

Aspen accumulates more of most nutrients, particularly Ca, than its common associates (Table 1). Aspen also has a much greater fraction of nutrients in the stem bark than other species (Table 2). The amounts of Ca annually accumulated in aspen stands are greater than the uptake by many agricultural crops. This suggests the possibility of significant soil changes due to the growth of aspen. If the Ca accumulated in the aspen biomass is not replaced by precipitation inputs or soil weathering, soil Ca will decline and soil pH will decrease. Such an effect was noted on two sites in Minnesota where soil pH declined about 0.5 pH units (Alban 1982). Soil pH also declined in Tennessee under oak, another Ca accumulator. The soil changes there were accentuated by acidic precipitation (Johnson and Todd 1987). If a site that has had soil Ca and pH lowered by aspen growth is harvested, soil changes should continue during the second rotation. But the rate of change is unknown and may be mitigated by feedback mechanisms. For example, the lowered pH may increase the rate of mineral weathering.

Nutrient accumulation by aspen stands can clearly affect soil characteristics at least on some sites. This should alert us to the possibility of site productivity changes. For example, radiata pine (*Pinus radiata* D. Don) and Norway spruce (*Picea abies* [L.] Karst.) grew less when logging slash was removed than when it was left on the site (Squire et al. 1985; Sterba 1988).

For aspen we have only a few case studies showing soil changes. Our knowledge of the relation between soil properties or processes and tree growth is too limited to draw firm conclusions, either in general or on a specific

Table 1. Aboveground biomass nutrient accumulations

Species	Age	Location	N	P	K	Ca	Mg	References
			kg/ha					
Aspen	40	Minnesota	368	47	287	858	58	Perala and Alban 1982
White spruce	39	Minnesota	389	59	234	734	41	Perala and Alban 1982
Red pine	39	Minnesota	356	43	180	302	59	Perala and Alban 1982
Jack pine	39	Minnesota	264	25	99	203	38	Perala and Alban 1982
Aspen	66	Minnesota	439	55	354	1589	112	Alban (unpublished)[a]
Aspen	47	Michigan	249	30	179	729	62	Alban (unpublished)[a]
Aspen	45	Wisconsin	207	21	107	441	43	Boyle et al. 1972
Aspen	65	Wisconsin	620	64	460	1100	90	Pastor and Bockhein 1984
Mixedwood[b]	60-95	Ontario	362	42	188	596	73	Hendrickson et al. 1987

[a]Data on file at the Forestry Sciences Laboratory, U.S. Dep. Agric., For. Serv., Grand Rapids, Minnesota.
[b]Aspen comprises 32% of the biomass of this stand. Red and white pine contribute most of the remainder.

Table 2. Percentage of nutrients in tree tissues[a]

Tissue	Nitrogen (%)		Calcium (%)	
	Aspen	Jack pine	Aspen	Jack pine
Foliage	24	25	4	10
Branches	22	30	25	26
Bole wood	23	32	20	36

[a]Perala and Alban 1982.

site. Leaving limbs, tops, and especially the bark on sensitive sites will minimize nutrient withdrawals and likely will not cause nutrient deficiencies.

Leaching Losses

Timber harvesting generally results in lessened evapotranspiration and increased water-flow through the soil. For most species and soils, harvesting will result in a flux of some nutrients through the soil for a few years, but the loss is generally small relative to that removed in the harvested timber (Mann et al. 1988). In aspen, stream flow increased 42% the first year after clear-cutting in Minnesota, and returned to precut levels in 9 years (Verry 1987). Clear-cutting aspen stands on a wide range of sites in Minnesota, Michigan, and Ontario caused essentially no leaching losses of N and P and just a few kilograms per hectare of K and Mg (Hendrickson et al. 1989; Silkworth and Grigal 1982; Richardson and Lund 1975). Only Ca loss was statistically significant, but even for Ca the loss was small and unlikely to have an impact on subsequent growth. The evidence is thus quite strong that aspen harvesting is unlikely to accelerate leaching loss of nutrients sufficiently to affect site productivity.

Organic Matter Loss

Loss of soil organic matter has been identified as one way that forestry operations might lower site productivity (Powers et al. 1990). A classic case occurred in New England, where clear-cutting caused a large decrease in forest floor weight (Covington 1981), but it was not clear whether the decreases represented actual losses from the site or simply a redistribution to deeper soil horizons. More intensive sampling showed that total carbon pools before and after harvest did not differ (Huntington and Ryan 1990). Neither were soil carbon changes found after clear-cutting a mixed hardwood forest in Tennessee (Edwards and Ross-Todd 1983). In an Ontario forest stand containing aspen, soil organic matter to a depth of 20 cm was not significantly different 3 years after harvesting (Hendrickson et al. 1989).

In a study of three sites having sand, loam, and clay soils, whole-tree harvesting of aspen did not change the soil carbon content (Table 3; Alban and Perala 1990). The increased oxidation of organic matter following harvesting is compensated for by the addition of logging slash and decaying root systems. Any accelerated organic matter loss would be short-lived because regeneration is usually rapid, the site is fully occupied quickly, and annual litterfall returns to pre-harvest levels within 5 years (Alban and Perala 1990). It seems that for most sites,

Table 3. Soil carbon content before and after harvesting[a]

	Sandy soil (Minnesota)		Loam soil (Minnesota)		Clay soil (Michigan)	
	Pre-harvest	Post-harvest[b]	Pre-harvest	Post-harvest	Pre-harvest	Post-harvest
Uncut	57	55	51	51	65	62
Clear-cut	58	62	51	49	76	72

[a]Forest floor plus top 25 cm of mineral soil.
[b]Post-harvest is the mean value for all years since harvesting (7 years for the sandy and clay soils and 4 years for the loam soil).

whole-tree aspen harvesting will not result in loss of soil organic matter by accelerated decomposition.

Soil Physical Disturbance

Soil displacement by root raking or erosion generally lowers productivity and often has detrimental off-site effects. It also creates adverse public reaction. For these reasons, most land managers attempt to keep soil displacement to a minimum, and good guidelines are available for doing so (Perry et al. 1989). Because factors other than site productivity largely determine how soil displacement is managed, it will not be discussed further in this review.

Soil compaction is perhaps the single most important site impact of forest management. Heavy machinery in both agriculture and forestry can, under some conditions, compact soils. This results in changes in soil strength, aeration, infiltration rate, and moisture and nutrient regimes. These changes can have dramatic effects on plant growth. Excellent reviews of forest soil compaction are available (Froehlich and McNabb 1984; Greacen and Sands 1980; Standish et al. 1988). Unfortunately, few unconfounded data are available on the impact of soil compaction on forest growth and there is virtually none for aspen. Froehlich and McNabb (1984) showed that decreased height growth in several conifers was directly related to an increased soil bulk density. When soil bulk density was increased by 70%, height growth was reduced by about 45%. Application of this relationship to other species on other areas is subject to gross errors. It is known from agriculture experience, for example, that soil compaction, by increasing fine pore spaces, can increase soil moisture-holding capacity, resulting in increased plant growth, particularly in dry years (Raghavan et al. 1981).

The complex interaction of plant species, soils, and climate make predictions of compaction effects on tree growth and the rate of soil recovery marginal at best. For aspen the information is equally meager. I am aware of only two studies in aspen that examine how harvesting affects soil compaction. In a study on two Minnesota sites and one Michigan site, harvesting was on snow-covered, frozen ground, in a purposeful attempt to avoid compaction. Not surprisingly, soil bulk density was not affected (Alban and Perala 1990). In an earlier study in north-central Minnesota, a 50-year-old aspen stand on a silty clay loam soil was tree-length harvested, and surface soil bulk density was increased from 1.15 g/cm^3 to 1.47 g/cm^3 on heavily disturbed areas with little recovery after one year (Mace 1971). Unfortunately, the effects of the compaction on tree growth were not reported. We are unable (on a site-specific basis) to reliably predict the impact of aspen harvesting on soil compaction or how it affects tree growth.

To address this lack of knowledge, the literature was reviewed comprehensively to evaluate the factors responsible for site productivity decline (Powers et al. 1990). Organic matter removal and soil compaction were the factors most often associated with productivity decline. A U.S. nationwide study was proposed to evaluate these two factors. Research plots have since been installed in Louisiana, California, and Minnesota. Three levels of compaction and three levels of organic matter removal are applied to a wide range of soils and forest types. The objective is to quantify the relationship between site productivity and the soil properties and processes controlling plant growth. Climate will be measured on each site because, even though management practices are unlikely to have an effect on climate, the impacts of compaction and organic matter removal on site productivity will be affected by climate and must be accounted for.

In the Lake States, the study will examine the aspen forest type. It is anticipated that the results will be applicable over a wide range of sites. Extension of the study to sites throughout the range of aspen would encompass a wide range of soils and climate and could provide powerful means to quantify the impacts of harvesting on site productivity.

SUMMARY AND CONCLUSIONS

If aspen harvesting affects site productivity, it does so by changing soil properties. Long-term nutrient accumulation by aspen can lower soil nutrients, particularly Ca. Such effects can be augmented by acid precipitation or increased precipitation. The impacts of such effects will be quite site-specific, and we currently have no

reliable method to assess the magnitude of the effect on site productivity.

Some harvesting impacts appear to be minor for many sites. Leaching loss of nutrients and accelerated organic matter loss appear to be small; however, such generalization must be tempered by the knowledge that aspen grows over a wide range of soils and climates.

Soil compaction is likely to alter site productivity in some cases, but our predictive ability is limited. The effects of soil compaction can be avoided on the most susceptible sites by harvesting when the soil is dry or frozen. Nevertheless, these mitigating practices would be put on a sounder and more rational basis if the impacts could be reliably quantified.

In general, our knowledge of management impacts on site productivity is based on case studies, most of which are retrospective. Extrapolation of results to new areas and new situations is risky. Therefore, in most cases the implications of a given forest management practice on long-term site productivity cannot be accurately assessed. What are needed to correct this deficiency are designed and replicated studies to manipulate the soil and to develop the relationship between site productivity and soil properties and processes. Such studies will quantify the key soil factors that can be monitored to assess the management impacts on site productivity.

Soil monitoring should be an integral part of forest management activities in the 21st century. That information, fed back to research, will suggest areas requiring further study, which will in turn refine and improve the monitoring guidelines. The complex problem of assessing harvesting impacts on site productivity can best be resolved by such a joint partnership between researchers and people directly involved in the management of forest lands.

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RENEWING DECADENT ASPEN STANDS

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ABSTRACT

Aspen (*Populus tremuloides* Michx.) with life left in the crown can usually be regenerated by root sprouts following clear-cutting, bulldozing, shearing, burning, or aerially applied phenoxy herbicide. About 4-5 m^2 basal area per hectare of well-distributed aspen are needed to provide sufficient roots to regenerate full stocking. Some stands regenerate sporadically without disturbance to form multi-storied, uneven-aged stands. Regeneration from seed is possible if mineral soil is exposed by scarification or fire, but it is less reliable than suckering.

INTRODUCTION

As aspen fulfils its expectation as useful raw material and we begin to manage the aspen forest, we notice that we are late in entering some stands. They may be largely intact but so riddled with decay to be unusable, or they may already be broken up into remnants. They likely are economically inoperable and can be renewed only at cost, sometimes with great difficulty or not at all, and with no immediate return. These stands are the focus of this paper, although whatever is said applies as well to stands that owe their decadence to high grading (e.g., Navratil et al. 1990). Prudent silvicultural practices usually prevent regeneration problems in stands that are normally economically operable.

The timing of decadence depends on inherent aspen stability and longevity and the speed of the break-up process. Stand renewal depends on the biological opportunities for regeneration, their limits, and our resolve to intervene with appropriately sound actions.

STABILITY AND LONGEVITY

Aspen is a disturbance-dependent early successional species that usually dominates a site only until it is replaced by more stability-dependent, shade-tolerant species. Most aspen stands are even-aged because they reproduced as suckers immediately after a disturbance. Although aspen clones readily expand into grasslands or shrub lands, human intervention or fire is essential to regenerate aspen on most sites where it is seral. If fire occurs about every 50 years and is hot enough to kill most of the stand, aspen will dominate most sites. Without fire, aspen is usually replaced within a single generation (Mueggler 1985).

Not all aspen stands are seral. Well-stocked, mature stands produce hundreds of ephemeral suckers that grow a few centimetres, die from lack of light, and reappear the next year (Baker 1918). As aspen canopies deteriorate, increased light enables some suckers to grow into saplings. In the west, where conifer invasion can sometimes take more than 1000 years, uneven-aged stands commonly develop this way. If they lack invading conifers, the community is stable—a *de facto* climax—and self-perpetuating. Aspen seems to form relatively stable communities at mid elevations and on southerly exposures; at high elevations and on northerly exposures it usually is replaced by conifers (Mueggler 1985). In the east, succession is determined by soil-water regime (Roberts and Richardson 1985).

Aspen longevity depends on cool growing seasons and therefore increases with latitude and

Perala, D.A. 1991. Renewing decadent aspen stands. *In* S. Navratil and P.B. Chapman, editors. Aspen management for the 21st century. Proceedings of a symposium held November 20-21, 1990, Edmonton, Alberta. For. Can., Northwest Reg., North. For. Cent. and Poplar Counc. Can., Edmonton, Alberta.

elevation. Aspen lives longer on calcareous soils (Shields and Bockheim 1981) and good sites (Baker 1925; Zehngraff 1949; Graham et al. 1963; Fralish 1972), although the oldest reported quaking aspen was 226 years old but only 12 m tall (Strain 1964). In the east, stands start to break up after 40-70 years. In the Rockies, stands commonly attain 120 years, and some persist to 200 years or so (Jones and Schier 1985). Commercial rotations range from about 35 years in the southern Lake States to about 120 years in the Rockies (Graham et al. 1963; Shepperd and Engelby 1983).

BREAKUP

Stand breakup begins when growth slows to the point where canopy gaps caused by mortality cannot be refilled. Heightened stresses from increased wind, sunlight, and therefore evapotranspiration, sap the vigor of the survivors. The process accelerates as more trees succumb and more gaps are created. Breakup takes as little as 3 years in the east (Fralish 1972). In the west, some clones deteriorate so fast that sucker production cannot keep pace with overstory mortality (Schier 1975), and the site converts to conifers or, on dry sites, to rangeland. Sometimes pathogens or defoliating insects can cause premature breakup. Chronically infested stands are inherently poor management risks and should be converted to another cover type (Schipper and Anderson 1976).

Breakup is generally, but not always, coincident with the extensive development of decay that weakens the tree and increases wind loss. Decay incidence and volume, the position and shape of rot columns, and the interaction of these with site quality differs among clones (Wall 1971), although genetics may not be as important as the micro-environment (Weingartner and Basham 1985).

REGENERATION POTENTIAL AND LIMITATIONS

Aspen can be regenerated sexually from seed or vegetatively by root suckering. The latter is by far the most practical, although seedling regeneration should not be totally discounted (Gullion 1990; Navratil et al. 1990). The advantage of an existing, well-established root system to produce numerous root suckers is readily apparent. Root suckers do not require stringent microclimatic conditions, and the genetic character of the new stand is known from the parent stand.

Jones and DeByle (1985), Schier et al. (1985a), and Perala (1991) reviewed the suckering process and limitations. In the west, most suckers arise from roots within 6 cm of the surface, and practically all arise from roots within 12 cm. Parent roots of aspen in the Lake States tend to be shallower, most within 3 cm. Severe burns increase the depth of sucker initiation. Most suckers grow from roots smaller than 1 cm in diameter. Few grow from roots greater than 3 cm.

Sucker development is suppressed by "apical dominance" over the roots exerted by auxin transported from the canopy. When aspen are cut, burned, girdled, or defoliated, auxin levels in the roots plummet. New suckers and preformed dormant primordia, buds, and shoots can then grow. Deteriorating clones often fail to regenerate because auxin even from declining crowns can still dominate the shrinking root system.

Cytokinins (synthesized in root meristems) in high ratios to auxins favor shoot initiation; low ratios inhibit it. These ratios increase when an aspen is cut because auxins no longer move into the roots, and cytokinins no longer move out.

Carbohydrate reserves in the parent roots fuel bud initiation and shoot growth until the shoot emerges from the soil surface and can manufacture photosynthate. Inadequate carbohydrate reserves do not significantly limit the number of suckers initiated but do limit those that reach the soil surface, especially from deep roots. Neither distance from the parent tree nor root age regulates suckering.

Low soil temperature limits suckering. High temperatures increase cytokinin production and may degrade auxin, thus stimulating suckering. Suckering is not inhibited by drought until water is no longer available from deep in the soil profile.

Sucker production varies much among clones, probably reflecting root carbohydrate reserves and hormonal growth promoters. Aspen seems genetically most uniform where environments are most severe; the greatest variation in the west is at intermediate elevations.

Aspen does not tolerate shade. Regardless of size, overtopped aspens deteriorate and eventually die. Sucker regeneration after partial cutting is proportional to the degree of overstory removal. Removing sufficient canopy to allow nearly full light is needed to produce a uniform and vigorous sucker stand.

Sucker production increases asymptotically with stocking of the parent stand. Poorly stocked aspen simply lacks the root densities needed for full regeneration. About 4-5 m^2/ha basal area are needed for adequate regeneration (Perala 1983; Doucet 1989).

REGENERATION PRACTICES

Sound, undamaged suckers are needed to provide a stand that is stocked well enough to meet management objectives. Excessive stocking is seldom a problem because aspen stands constantly thin themselves (Walters et al. 1982; Shepperd and Engelby 1983).

Logging may not be an option in decadent stands unless concessions or payments are awarded the operator. Yet logging, especially clear-cutting, stimulates aspen suckering as well as any treatment (reviews by Perala and Russell 1983; Schier et al. 1985b; Davidson et al. 1989; Doucet 1989; Navratil et al. 1990). Partial cutting produces suckers on fewer roots, and they develop into inferior stands in competition with the overstory (Sampson 1919; Schier and Smith 1979). Partial cutting reduces future yield (Walters et al. 1982) and restricts silvicultural options. Once partially cut stands sprout, future entries can only damage the new stand.

Only when aspen is cut in the dormant season or in spring can suckering be substantial during the ensuing growing season (Schier et al. 1985b). Regeneration generally is adequate when aspen is cut in the summer, although it will not be numerous until the next year. The later in the growing season that suckers emerge, the less hardened and frost sensitive they are in the fall. Sometimes peak sucker production lags for several years (Schier et al. 1985b). Meanwhile, an understory can become more competitive before aspen suckers arise. Clear-cut aspen stands occasionally do not regenerate, especially on level, poorly drained sties (Bates et al. 1990).

Trafficking by harvesting machines reduces suckering in skid trials and landings (Schier et al. 1985b) and can inhibit regeneration over the entire cut area on sites with low soil strength or if operations are prolonged over the growing season (Bates et al. 1990). Aspen regeneration also may fail under excessive slash and felled cull material (Schier et al. 1985b) but seldom on pulpwood clear-cuts having good utilization (Zasada 1972; Bella 1986).

Aspen slash usually is not treated. It is a negligible fire hazard that decays rapidly and is quickly hidden by the dense new growth. Scattered slash also provides suckers some protection from browsing (Schier et al. 1985b).

A fire sufficiently hot to kill an aspen stand will stimulate abundant suckering. A weak fire may only blacken the forest floor, whereas a hot fire can consume it entirely. Solar energy will elevate soil temperatures, depending on how much insulating forest floor remains. The cooler the aspen site, the more advantageous fire is to regenerate aspen.

The heat from an extreme fire can kill roots in the surface 2-3 cm of soil (Horton and Hopkins 1965). Suckering depth can be increased to 10 cm by a hot fire compared to 6-7 cm under a moderate burn (Schier and Campbell 1978). Some suckers will arise after any fire, even if the aspen canopy remains intact (Maini and Horton 1966a), although sucker vigor suffers under a live overstory (Barmore 1968). A fire that kills most or all of the overstory seems ideal, but excessively hot fires should be avoided (Perala 1974).

Where fire can be safely used, it is an efficient regeneration tool, not only for suckers but for aspen seedlings that exploit exposed mineral soil. It is easiest to burn mixed stands having coniferous slash. Burning is best when the surface soil is damp to protect shallow aspen roots and to contain the fire. Hardwood slash is difficult to burn (Perala 1974), but once started,

fires can be nearly uncontrollable (Alexander 1982). Many aspen stands, especially those with only an herbaceous understory, do not readily carry fire (Brown and Simmerman 1986).

Herbicides that kill aspen crowns without killing the roots can stimulate good sucker regeneration (Brinkman and Roe 1975). Aerial spraying is inexpensive, and compared to burning, it is less sensitive to weather (DeByle 1976). A water emulsion of 2.8 to 3.4 kg (acid equivalent) per hectare of low volatile 2,4-D ester seems to work well (Brinkman and Roe 1975). Other foliar-active herbicides that kill roots, like glyphosate, might control undesirable residuals like balsam poplar (*Populus balsamifera* L.) without harming aspen if applied after summer logging and before aspen suckers emerge.

Girdled aspen produce few suckers (Smith et al. 1972; Schier and Smith 1979) because favorable cytokinin to auxin ratios do not develop, the root system dies back, and the lingering live crowns cast too much shade.

Wounding or cutting of roots stimulates suckering (Barth 1942; Sandberg 1951; Maini and Horton 1966b; Steneker 1974), even if a root is severed at a single point (Farmer 1962; Schier et al. 1985b). Although disking stimulates understocked aspen stands to sucker, the injury to parent roots is excessive. Fewer suckers survive, their growth is slower, and their internal quality suffers from increased strain and decay (Perala 1972, 1977; Brinkman and Roe 1975; Basham 1988).

Shearing aspen off at the stump with a sharp bulldozer blade can regenerate dense new aspen stands. The parent root system is least disturbed in frozen soils (Perala 1983). Suckering can also be stimulated greatly by bulldozing and tipping aspen out of the ground (Schier et al. 1985b).

Sometimes little deliberate action is needed to regenerate aspen. Grazed stands that have begun to sucker may be completely regenerated by excluding livestock for a few years. Excessive pressure by ungulates can deter aspen regeneration, and limited browsing may suppress apical control and allow abnormally dense stocking. Light browsing forces single dominant shoots and has little effect on stem form (Schier et al. 1985b).

Because dormant-season treatments promote the best suckering, they should be used whenever possible in decadent stands. Only when the preferred treatment, e.g., logging, might not control a strong understory or provide sufficient soil warming should a summer treatment be considered. Decadent stands that we want to renew need all the help we can give them.

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THE POPLAR COUNCIL OF CANADA: ORGANIZATION, HISTORY, AND ACHIEVEMENTS IN 1990

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The Poplar Council of Canada is a nationwide, non-profit, incorporated, voluntary organization consisting of private, corporate, and government members interested in all aspects of poplar culture and utilization. It was established in 1978. The Council currently has about 200 private members and 50 corporate, government, and university members.

The council has an executive committee and a board of directors. The executive committee includes the chairman, two vice-chairmen, a past chairman, and a secretary treasurer. The board of directors consists of the chairmen of technical committees on planting and silviculture, economics, utilization, protection, and genetics, and also representatives of industrial fields, universities, provincial and federal governments, poplar farmers, and a public relations officer. I am currently the chairman. Past chairmen include Russell Johnson, Domtar Ltd.; Gilles Vallee, from the Quebec provincial government; Brian Barkley, from the Ontario provincial government; and Donald Blouin, from Malette Waferboard.

These are the council's objectives:

1. to promote the growth and utilization of poplar trees;
2. to facilitate the exchange of information and plant materials;
3. to sponsor meetings, workshops, and technical sessions for landowners, producers, users, and scientists to discuss mutual problems and future directions;
4. to evaluate current knowledge to encourage further research;
5. to represent Canada at the International Poplar Commission of the United Nations' Food and Agriculture Organization.

Over the years, annual meetings have been held in locations across the country, such as southern and eastern Ontario (Kemptville, Ottawa, Toronto), Quebec, Saskatchewan, British Columbia, northern Ontario, and Alberta. Some of these were held jointly with the Poplar Council of the United States. Eight proceedings were published with presented papers from annual meetings, focusing on aspen management, hybrid poplar culture, and aspen utilization.

Two newsletters are published annually and are mailed to members. Newsletters focus on the national and international scene.

Other publications, produced in cooperation with government agencies and industry, are:

Canadian activities in poplar production and utilization (1979, ENFOR);
Guide to the identification of poplar clones in Ontario (1984, OMNR); and
Directory of secondary wood using industries in Alberta (1989, CAFRDA).

The council's contributions to the International Poplar Commission (IPC) have been recognized. Past chairman Gilles Vallee, Quebec, served two terms as the co-chairman of IPC. John Balatinecz and I are chairmen of IPC subsidiary bodies, and Gilles Vallee and I are members of the IPC executive committee.

The council's present program includes, among others:

Zsuffa, L. 1991. The poplar council of Canada: Organization, history and achievements in 1990. *In* S. Navratil and P.B. Chapman, editors. Aspen management for the 21st century. Proceedings of a symposium held November 20-21, 1990, Edmonton, Alberta. For. Can., Northwest Reg., North. For. Cent. and Poplar Counc. Can., Edmonton, Alberta.

1. a study of the use of poplar (including aspen) in wood-using industries of Canada;
2. a report on ecology, management, and use of aspen in the prairie provinces (with Forestry Canada);
3. a poplar utilization handbook (with the province of Alberta);
4. a manual for field classification of wood defects in aspen (with Forestry Canada and the province of Alberta); and
5. a list and characteristics of poplar and willow clones used in Canada (with Forestry Canada, IPC, and IEA).

In 1990 the Poplar Council of Canada underwent a renewal. Our secretariat moved from Toronto to the west, to Alberta, emphasizing the need to focus on Canada's long-neglected rich aspen resource. The new secretariat, headed by Stan Navratil, reactivated the program. This aspen management symposium exemplifies the council's achievements in 1990.

We have also witnessed the following in 1990:

1. the rebirth of the Poplar Council of Canada newsletter, in an improved and professional format;
2. a new drive for membership, with a new pamphlet on the council's program and goals;
3. useful changes in the board of directors composition, aimed at a reactivation and more-complete representation of different fields of activities and provinces;
4. the publication of several important documents by the council and/or in cooperation with its members, such as the proceedings of the 1989 annual meeting and a manual of field classification of wood defects in aspen;
5. good progress on several projects, such as the study of poplar in the wood-using industries in Canada and a monograph on ecology, management, and use of aspen in the prairie provinces.

The council represented Canada internationally and contributed reports to the meeting of the International Poplar Commission's Executive Committee and its subsidiary bodies in Argentina in May 1990.

SESSION III

WILDLIFE, ENVIRONMENT, AND ASPEN MANAGEMENT

Moderator: R. Udell
Weldwood of Canada Ltd.
Hinton Division
Hinton, Alberta

WILDLIFE AND ASPEN MANAGEMENT: A GOVERNMENT PERSPECTIVE

H. Wollis
Alberta Forestry, Lands and Wildlife
Edmonton, Alberta

ABSTRACT

The effect of aspen logging on wildlife habitat is examined from the viewpoint of the wildlife manager. Long ignored by loggers, aspen once could be relied upon to maintain some structure in the forest following coniferous harvest. Aspen logging brings more areas into the "managed forest." The manager must decide what kinds, how much and the interspersion of wildlife habitat that must be available throughout the managed forest over the harvest rotation. While many of these challenges are similar to those faced in the coniferous forest, there are some differences. The author discusses these differences and management solutions.

INTRODUCTION

Only a few years ago, logging was something that happened out in the hinterland, in places few people heard of—Grande Prairie and Hinton, for example. Then, suddenly, things changed. Second pass cuts began; the Alberta government committed most of its timber; and the value of aspen became recognized. At about this time, the public discovered the timber industry.

From the government perspective and, more specifically, from the Fish and Wildlife Division perspective, this increased harvest represented widespread habitat change. Except for a few game species and basic prohibitions on killing, wildlife in the aspen forest managed itself.

In the 21st century we can no longer afford to manage by accident. The forestry industry is accountable for its actions. How will the industry ensure that the pileated woodpecker (*Dryocopus pileatus*) will remain after the chainsaws and feller bunchers are gone? There is no magic formula. We can set objectives, we can offer some advice, but in some cases we will have to work together to find the solution. Ross Waldron said at this conference that we need the will and commitment for sustainable development. His statement also applies to wildlife habitat.

I think many people would agree with the statement, "logging aspen is good for wildlife." Certainly, as proof, one could point to the many habitat enhancement projects in which the Alberta Fish and Wildlife Division has been involved. Let's probe the validity of this statement by looking at the diversity of wildlife habitat in the aspen forest.

Different wildlife species have adapted to the different habitats offered by various stages in the life cycle of the aspen forest. There are about 400 wildlife species in Alberta, although not all are found in aspen forests. Quinlan et al. (1990) summarized habitat use by wildlife in the Edson Forest. The study eliminated transient and incidental species, fish, ducks, and those not affected by logging, such as mountain species. This left about 130 species remaining. Table 1 summarizes wildlife use of the different stages in the life cycle of aspen. Each species in the list is representative of a group whose habitat needs are met primarily in this particular habitat type.

Following fire or logging in an aspen stand, a grass-forb habitat develops. Under good growing conditions aspen sprouts quickly, so this could be a very transient habitat type. Structurally, it is a simple habitat type, but it provides considerable food for herbivores and seed-eating species. About 14 wildlife species seek this type for primary habitat; the representative species is the Savannah sparrow (*Passerculus sandwichensis*).

Wollis, H. 1991. Wildlife and aspen management: A government perspective. *In* S. Navratil and P.B. Chapman, editors. Aspen management for the 21st century. Proceedings of a symposium held November 20-21, 1990, Edmonton, Alberta. For. Can., Northwest Reg., North. For. Cent. and Poplar Counc. Can., Edmonton, Alberta.

Table 1. Wildlife indicator species for different age classes of aspen

Indicator species	No. of species represented	Habitat type[a]							
		1	2	3	4	5	6	7	8
Savannah sparrow	14	*							
Clay-colored sparrow	13		*						
Chipping sparrow	30			*					
Warbling vireo	24			*					
Hermit thrush	24					*		*	
Ovenbird	26					*	*		
Ruffed grouse	31				*	*	*	*	*
Hairy woodpecker	33					*	*	*	*
Great gray owl	30							*	*
Tennessee warbler	9								*
Pileated woodpecker	48							*	*

[a]1 = grass forbs, 2 = upland shrubs/saplings, 3 = edge, 4 = immature (25-50 yr), 5 = mature mixedwood forest (50-80 yrs), 6 = mature deciuous, 7 = old growth mixedwood (>80 yr), 8 = old growth deciduous (>80 yr).

The upland shrub-sapling stage is still a structurally simple habitat; however, it provides food and cover for 13 species that are highly dependent on this type. Several sparrows, including the clay-colored sparrow (*Spizella pallida*) and the snowshoe hare (*Lepus americanus*) are among the species using this type.

Many species require a combination of habitat types and occur in and around these edge habitats. A grass-forb type adjacent to mature forest will offer habitat to species such as white-tailed deer (*Odocoileus virginianus*) and elk (*Cervus elaphus*), which seek shelter in the forest and feed in the open. The chipping sparrow (*Spizella passerina*) and the warbling vireo (*Vireo gilvus*) are representative of the 30 wildlife species that seek this type.

The immature habitat type, which is about 25 to 50 years old, can best be described as the "doghair" aspen type. No wildlife species are restricted to this type, although some species, such as the ruffed grouse (*Bonasa umbellua*) use such stands, largely for shelter.

Beyond 50 years, aspen stands mature to the mature deciduous and mature aspen-conifer mixedwood type. This is the preferred stage for logging; it is also the preferred habitat of 26 wildlife species, such as the ovenbird (*Seiurus aurocapillus*). This stand type has considerable structure. Despite the closed canopy, there is sufficient light to grow grass, forbs, and a variety of woody shrubs. Wildlife find secure nesting, perching, and feeding sites high in the canopy. As trees decay and die, woodpeckers begin to feed and to excavate nest holes, which are subsequently used by other birds.

As the stand ages beyond 80 years, more and larger trees die, providing additional feeding and nesting sites. The opening canopy provides opportunity for more forbs and shrubs, which allow animals such as the pileated woodpecker to find both shelter and forage within the stand. It may be surprising to foresters to realize that 48 species depend on this habitat type. (Note: the numbers of representative species used in this discussion include those in conifer stands.)

IMPLICATIONS

One might say that logging is good for the clay-colored sparrow and the 12 other species that select upland shrub habitat. On the other hand, logging would be bad for the pileated woodpecker and the seven other species it represents in the old-growth forest. More importantly, if one considers the managed forest where the harvest rotation is 60 to 80 years, there will never again be an old-growth element in that stand. Where will the pileated woodpecker live?

Logging is therefore neither good nor bad for wildlife. Only from a management perspective can we use these anthropomorphic terms. Logging is good if it achieves the objectives set out by the manager. It is bad if it doesn't. Consider the example of the Fish and Wildlife Division clearing aspen for moose. Due to forest fire control much aspen has grown past the stage suitable for moose. Clearing the aspen returned the stand to the habitat type suitable for moose. This achieved the objectives, so logging was good.

Another element of aspen logging that is of concern is the integrated harvesting concept. In the past, not only did we not have to worry about logging in large parts of the province, we did not have to worry about embedded stands of aspen or residual patches. Now the Alberta Forest Service requires that aspen in predominantly coniferous stands also be harvested. We have to consider the implications of these decisions on wildlife.

The Nature of Logging

In situations where the wildlife manager agrees that logging might improve habitat for target species, the amount of benefit will depend on the type of logging. For example, Gullion (1984) said that optimal ruffed grouse habitat in Minnesota would be achieved by cutting 4-ha blocks every 10 years over a 40-year rotation. Neither the cut block size nor rotation length are viewed favorably by industry in Alberta, where cut blocks to 100 ha over 60- to 80-year rotations are allowed.

Access

Certain factors can negate the potential benefits that logging provides to wildlife species. Creation of access is a major concern. Large hunted species such as elk, moose, and deer will not gain benefits from a cut block if logging provides access to legal and illegal hunting.

LACK OF INFORMATION

There are significant gaps in our knowledge about aspen and the wildlife that inhabit aspen forests. We heard at this conference that we don't have maps of old-growth aspen forests even if we did want to manage them. We have little or no data on the distribution of many of the 130 wildlife species. We don't know how fast species will reinhabit a cutover, whether cutovers differ significantly from burned areas with respect to wildlife use, or what the minimum stand size is for species use.

ADMINISTRATIVE DIFFICULTIES

With a market now available for aspen, Crown and private land covered by aspen in the northern agricultural portion of the province offers additional economic return. Private landowners may use this opportunity to convert aspen-covered land to marginal cropland or pasture. This continues the erosion of native habitat for wildlife. There is valuable aspen on Crown land on the agricultural fringe that is sought for agricultural expansion. If the government authorizes "liquidation cuts" of the land before selling it, another loss of habitat will result, possibly at an accelerated rate. Meanwhile, elsewhere in the province, the Buck for Wildlife program of the Fish and Wildlife Division is paying landowners to plant trees to convert marginal farmland to wildlife habitat.

Where aspen and conifers exist on the same block of land, the timber manager tries to integrate the harvest. Often one operator will harvest the aspen and another will take the conifers. This can cause problems. For example, the wildlife manager will often request that the road be taken out immediately following harvest to minimize access problems. If the aspen operator must wait for the coniferous operator to remove his logs, delays could result, leaving access open for a year or more.

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Another element of aspen logging that is of concern is the integrated harvesting concept. In the past, not only did we not have to worry about logging in large parts of the province, we did not have to worry about embedded stands of aspen or residual patches. Now the Alberta Forest Service requires that aspen in predominantly coniferous stands also be harvested. We have to consider the implications of these decisions on wildlife.

The Nature of Logging

In situations where the wildlife manager agrees that logging might improve habitat for target species, the amount of benefit will depend on the type of logging. For example, Gullion (1984) said that optimal ruffed grouse habitat in Minnesota would be achieved by cutting 4-ha blocks every 10 years over a 40-year rotation. Neither the cut block size nor rotation length are viewed favorably by industry in Alberta, where cut blocks to 100 ha over 60- to 80-year rotations are allowed.

Access

Certain factors can negate the potential benefits that logging provides to wildlife species. Creation of access is a major concern. Large hunted species such as elk, moose, and deer will not gain benefits from a cut block if logging provides access to legal and illegal hunting.

LACK OF INFORMATION

There are significant gaps in our knowledge about aspen and the wildlife that inhabit aspen forests. We heard at this conference that we don't have maps of old-growth aspen forests even if we did want to manage them. We have little or no data on the distribution of many of the 130 wildlife species. We don't know how fast species will reinhabit a cutover, whether cutovers differ significantly from burned areas with respect to wildlife use, or what the minimum stand size is for species use.

ADMINISTRATIVE DIFFICULTIES

With a market now available for aspen, Crown and private land covered by aspen in the northern agricultural portion of the province offers additional economic return. Private landowners may use this opportunity to convert aspen-covered land to marginal cropland or pasture. This continues the erosion of native habitat for wildlife. There is valuable aspen on Crown land on the agricultural fringe that is sought for agricultural expansion. If the government authorizes "liquidation cuts" of the land before selling it, another loss of habitat will result, possibly at an accelerated rate. Meanwhile, elsewhere in the province, the Buck for Wildlife program of the Fish and Wildlife Division is paying landowners to plant trees to convert marginal farmland to wildlife habitat.

Where aspen and conifers exist on the same block of land, the timber manager tries to integrate the harvest. Often one operator will harvest the aspen and another will take the conifers. This can cause problems. For example, the wildlife manager will often request that the road be taken out immediately following harvest to minimize access problems. If the aspen operator must wait for the coniferous operator to remove his logs, delays could result, leaving access open for a year or more.

TOWARD A SOLUTION

The large-scale commercial harvest of aspen is a reality. The wildlife manager and the timber manager must work together to understand the objectives of the resources and make decisions that accommodate both. A previous speaker said every log of merchantable timber is committed in some forests. How do we then sit down to discuss multiple use or integrated management if one sector has already taken its share of the pie? Logging greatly modifies habitat. The wildlife manager must ensure that the appropriate diversity and distribution of habitat remains following logging. He must, over the harvest rotation of the area, ensure that the age classes are balanced to prevent the exclusion of species. We need to fill the data gaps by gathering good wildlife habitat information.

We can apply present knowledge to this problem. Here are some thoughts.

1. Some management of old-growth aspen is required, even though much of the forest will never be cut because of such things as steep slopes, unmerchantable stands, and riparian stream buffers. Because aspen can achieve old growth status in 80+ years, such management may be feasible. How much management, where to do it, and what sizes of stands should be managed are questions that remain.

2. Maintaining diversity in cut blocks is important. Casual observation of bird and mammal signs on a 6-year aspen clear-cut near Edson, Alberta, vividly illustrated the value of leaving blocks for wildlife diversity.

3. Buffers around ponds must be maintained to provide nesting habitat and cover for many species, such as the bufflehead (*Bucephela albeola*), which uses ponds but requires large dead trees with nesting cavities.

4. Further diversity could be maintained by retaining structure within the cut blocks. Snags, or as a colleague in British Columbia calls them, wildlife trees, could be left. The best ones are large ones with broken tops. Leaving dead, downed logs also retains structure within the cut block.

5. If we look back to the ruffed grouse example, where cut block sizes are likely to be larger than 4 ha, the blocks could be improved by leaving islands of mature trees with a minimum size of 0.2 ha every 200 m. This provides a source of aspen catkins for winter food.

6. Retaining patches of conifer scattered throughout the aspen stand provides some diversity. Embedded stands could be left; advanced regeneration could be left through selective cutting; or small patches of conifers could be planted after aspen is harvested. We heard that this practice is a feasible way to reforest compacted areas such as landings and skid trails.

7. Selective cutting that leaves some balsam poplar could preserve some structure in the forest. Balsam poplar is rarely used commercially. Even these few trees will be used for perching, feeding, nesting, and shelter. They are valuable to wildlife even after they have fallen.

ACCESS MANAGEMENT

There are many physical, administrative, and planning methods to managing access. Rollback (using unmerchantable logging debris to make roads impassable) is one method of physically preventing access. Most methods are not unique to aspen-harvested areas, so I won't pursue this point.

CONCLUSION

I hope I have given the foresters in the audience an appreciation of what the Fish and Wildlife Division perspective is on aspen harvesting. Wildlife and aspen did quite well together before there were foresters and wildlife biologists. As I said earlier, there is a greater onus on the timber companies to factor wildlife considerations into their decision. Let's hope we can work together to manage the forests instead of only the trees.

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PEOPLE, WILDLIFE, AND ASPEN: A WILDLIFE USER'S PERSPECTIVE

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ABSTRACT

Wildlife users spent an estimated $300 million in 1987 on trips to hunt and observe wildlife in the aspen forests of the prairie provinces. Hunters and nonconsumptive users of wildlife differ from each other and from the general population of Canada. Nonconsumptive users are likely to increase in the next century. A large segment of the urban population is interested in wildlife as part of general environment concerns. Hunters want high game populations, road access, and an agreeable hunting experience. Nonconsumptive users want biodiversity, chances to view uncommon species, and aesthetically pleasing landscapes. Urban environmentalists want primeval forests. Management for the goals of hunters requires that stands of various ages be interspersed. Nonconsumptive users demand protection of all habitats and also scenic amenity. Environmentalists' demands may be addressed by consultation and by education programs, by reserving extensive areas for parks and ecological reserves, and by sensitive landscape management.

INTRODUCTION

This is the age of participatory democracy. The people insist upon involvement in decisions on public policy, including those policies affecting management of Crown lands. The Canadian population today is better educated, more affluent, and more mobile than before. People have greater leisure time and are in touch through electronic communications. They can spawn movements capable of wielding substantial political clout, frequently before those involved in institutions realize what is happening. In wildland management, wildlife users are a prominent influence.

As a group, wildlife users have a broad spectrum of interests (Duffus and Dearden 1990). New users are largely nonconsumptive, and their number and economic involvement has reached impressive levels. In 1987, 21% of people in the prairie provinces made trips specifically to view and study wildlife, mostly by bird watching (Filion et al. 1989). While engaged in those activities, they spent $472 million. In comparison, 10% of prairie province residents spent $231 million on hunting. Over 90% of the population were involved in some wildlife-related activity during that year.

Most larger centers of population in the prairie provinces lie along the boundary between forest and grassland. To the north is closed aspen forest and mixedwood; to the south is prairie. In the absence of data on selection of ecoregions by wildlife users, it seems reasonable to assign half of their expenditures to the forest ecoregions. The southern forest fringe, which is composed largely of aspen or aspen-dominated stands, receives much of both the consumptive and nonconsumptive wildlife user activity because it is accessible. Therefore, the expenditures by wildlife users in aspen-dominated cover types in Manitoba, Saskatchewan, and Alberta in 1987 can be estimated at about $300 million, a significant amount of money. In addition, many intangible benefits flow from outdoor recreation in terms of mental health and increased physical fitness.

WHO ARE THE USERS?

Users of wildlife include those who consume animals (hunters and trappers) and

Telfer, E.S. 1991. People, wildlife, and aspen: A wildlife user's perspective. *In* S. Navratil and P.B. Chapman, editors. Aspen management for the 21st century. Proceedings of a symposium held November 20-21, 1990, Edmonton, Alberta. For. Can., Northwest Reg., North. For. Cent. and Poplar Counc. Can., Edmonton, Alberta.

nonconsumptive users like birdwatchers, naturalists, and urban environmentalists. Recreational hunters are the largest class of consumptive users. The line between subsistence and recreational hunters is hard to draw. Although few people in the aspen forest zone depend entirely on hunting and trapping for their livelihood, many depend on game meat to stock their freezers and on trapping to supplement their income.

Aboriginal people are a special group of consumptive users because of treaty rights that allow them to take wildlife whenever and however they wish on unoccupied Crown lands. They use wildlife both for subsistence and recreation.

Only 2% of the population of the prairie provinces, or about 67 000 people, trap (calculated from data in Filion et al. 1989). Trappers are scattered throughout the region. Perhaps 25% are in the aspen-dominated forest.

The most notable group of nonconsumptive users is the birdwatchers. Others have a deep interest in all living things and a penchant for nature study and drawing or photographing animals.

There is a large group of urban people who are concerned about the welfare of wildlife but who seldom make trips to participate in wildlife-related activities and have little first-hand knowledge of wildlife, resource management, or the natural world. These urban environmentalists insist on being involved in decision-making concerning wildlife management and, increasingly, in wildland management.

There are important differences between consumptive and nonconsumptive users (Fig. 1). Hunters are rural and less educated compared to the general population but are older and have substantially higher incomes. On the other hand, nonconsumptive users are similar to the general population in urbanization and income but are better educated and older. The increasing levels of education and urbanization and the aging of the population suggest that the proportion of nonconsumptive users will increase. Hunting depends on easy access to hunting areas. As the rural population declines, fewer people will have those opportunities, and there will probably be fewer hunters in the 21st century. However, 25% of hunters are under 25 compared to only 20% of the general population and 21% of nonconsumptive users (Filion et al. 1989). This interest by the young plus the attraction of hunting for more affluent people suggests that hunting will remain highly popular with a small percentage of the population.

There was considerable overlap in wildlife-related activities in 1987. Filion et al. (1989) reported that 8% of Canadians both hunt and engage in nonconsumptive uses. Thus, 80% of hunters are also active in other wildlife-related activities. Those individuals also made 40% of all the estimated expenditures on wildlife in 1987.

GOALS OF WILDLIFE USERS

Each group of wildlife users has certain requirements for pursuit of its recreational and subsistence interests. Hunters want substantial populations of game animals, a quality hunting experience, and road access. Nonconsumptive users want biodiversity, an equitable distribution of numbers of animals among species, and little human disturbance. Urban environmentalists want the forest primeval.

To achieve the high game populations demanded by hunters, an adequate mix of high-quality cover and food-producing habitat is needed. Wildlife regulatory agencies must also do their part through creative regulation, adequate enforcement, and effective information and education to protect breeders and to allow the population to build up.

The quality of the hunting experience is an individual thing. To some people the hunt is a social event, and a quality experience means to take the field with a large group. Others prefer to hunt alone. For most, a good hunting experience depends on their perception of the behavior of other hunters.

Hunters value road access to the forest. A moose (*Alces alces*) once killed cannot be shot again. The next hunter must go farther into the bush. However, a succession of birdwatchers can look at the same singing male yellow warbler (*Dendroica petechia*), so access to the interior of the forest is less critical to them.

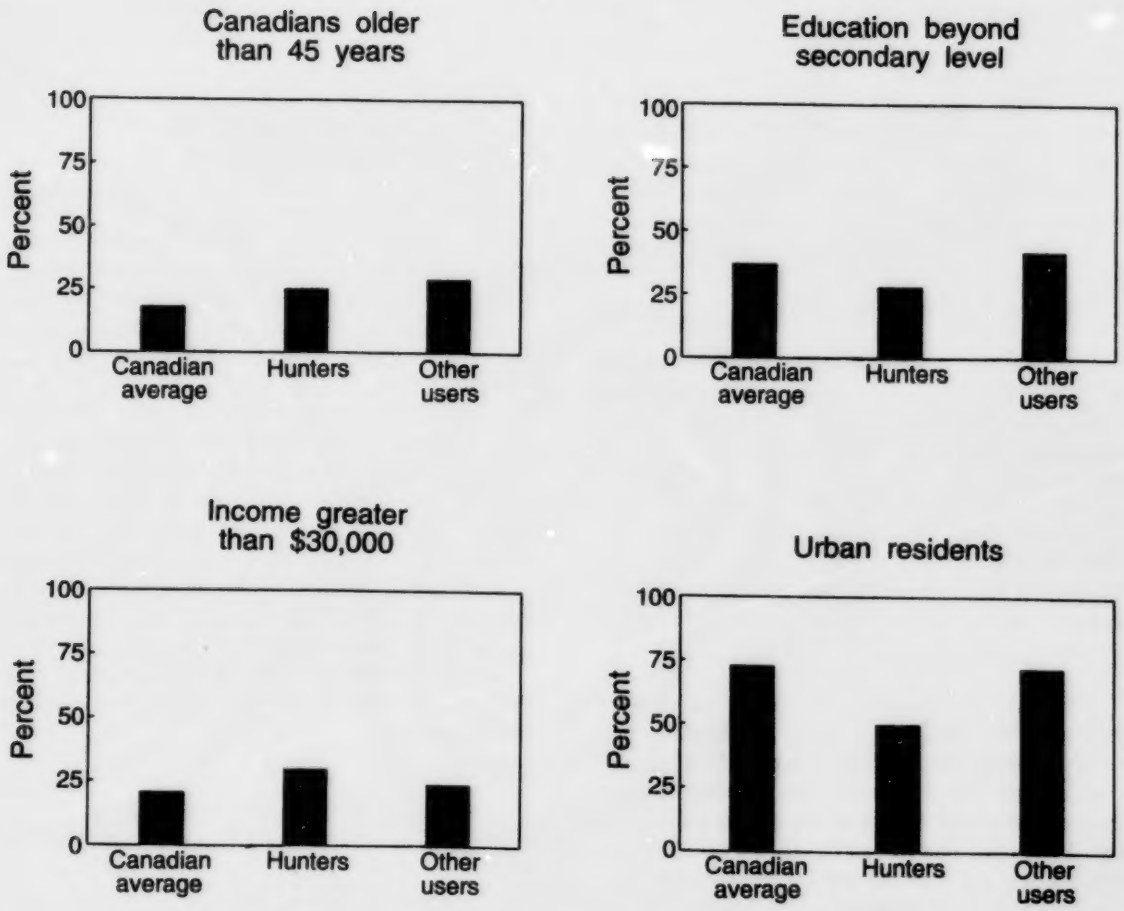

Figure 1. Some characteristics of wildlife users compared to the general population of Canada (from data presented by Filion et al. 1989).

Control of access is an important tool in the management of big game harvests. It is a subject on which foresters and wildlife managers can cooperate to protect the breeding stock of ungulates to allow numbers to build up on the supply of forage created by logging.

Nonconsumptive users want to maintain the full range of wildlife species that occurred on the area in presettlement times. This goal results from their conservation ethic and their interest in observing a variety of species. They also prefer uncommon species to be present in sufficient numbers to be found and observed.

Nonconsumptive users are much more likely to be concerned with man-made disturbance of the landscape than are hunters. The latter are engaged in an activity which, like logging, is consumptive. Nonconsumptive users stress naturalness. They question the morality of both hunting and timber cutting. However, active nonconsumptive users do get out into the forest, and they come to understand something of natural processes. It is therefore usually possible to come to understandings with them about specific situations. The price of such accommodations involves modification of clear-cut size and the planning of cut layouts and harvest scheduling to preserve scenic amenities.

Urban environmentalists are urban people who observe wildlife incidentally but seldom make wildlife-oriented trips. They are, however, concerned, confused, and upset about the state of the world's environment. Their information sources are television and other media, and they frequently lack the knowledge or experience necessary to evaluate what they hear. Many fall back on a line of thought that has always been present in the culture of the western world: primitive is good, civilized is bad.

Primativist thinking has always existed in tension with concepts of progress. In the great myth of creation that begins the Bible we have Adam and Eve living in and tending God's garden, an image of the hunting and gathering life. However, they eat of the fruit of the tree of knowledge and become self aware (Genesis 3:1-11; 22; 23). God is pained by this but there is no going back to the old state. The punishment for the humans is banishment from the garden and the necessity of earning their living by agriculture (Genesis 3:17-19). This formulation is over 2500 years old, but even at that time in the Middle East it appears that there was nostalgia for the primitive.

Later, the Greeks and Romans felt that mankind had become immoral and debased by the debilitating influences of civilized life. They hailed the superior courage, straightforwardness and loyalty of the more primitive Celts and Germans. Respect for wild nature was maintained through medieval times by the monastic movement (Bratton 1988). In the 18th century, Jean-Jacques Rousseau advanced the idea of the "noble savage" (Nash 1982). Man was originally good but was corrupted by civilized living. The same theme was expanded in more modern times by Henry David Thoreau and John Muir and by many 19th century romantic painters, poets, and musicians (Nash 1982). In the late 20th century, when materialism and naive views of progress have come unravelled, the urban masses yearn for simplicity and again idealize the primitive. The intellectual model is ready at hand. It is understandable then that the gut reaction of concerned urbanites should be that forest land, which looks like wilderness to them, should remain wild, and that clear-cuts, plantations, and biocides seem like a rape of the earth mother. It is small wonder that the forest industry has such a uniform record of failure in political confrontations with these people. There is a large minority who believe that loggers and hunters have to be stopped!

Countering this climate of opinion requires a sophisticated approach. The problem is heightened because there are few people with whom to negotiate solutions. Who speaks for or can control a grassroots social movement? Public consultation, good educational programs, and dissemination of information are obviously important. Willingness to compromise on land use and a handling of the forest landscape in a manner sensitive to the perceptions of urbanites is critical.

ASPEN MANAGEMENT FOR WILDLIFE USERS

Hunters are relatively easy to satisfy. They are most interested in ungulates like moose, elk (*Cervus elaphus*), mule deer (*Odocoileus hemionus*), and white-tail deer (*O. virginianus*), which obviously benefit from logging and the browse

supply it creates. However, ungulates must have cover (see Timmermann, this symposium, for a review of ungulate habitat requirements). Hunters, therefore, look for diversity in stand age classes with an interspersion of stands old enough to provide cover. The preservation or introduction of conifer stands in aspen areas is valued for the same reason.

The desire of nonconsumptive users for biodiversity and enhanced populations of uncommon species requires the maintenance of the full variety of habitats on rather small land units. In particular, snag habitat for cavity-nesting and bark-foraging species has to be maintained and its future supply guaranteed. Deadfall and woody debris provide another habitat of the natural forest that has to be planned for in future rotations. Fewer species are dependent on old growth in aspen than in conifer forests; however, snags and large live trees are important habitat for some species and should be provided for in the management process.

The desire of nonconsumptive users for a wide range of habitats and scenic amenity dictates a flexible approach to management. This includes variety in block sizes and tailoring of the shape of cut and leave-blocks to fit the topography. It will often call for identifying critical wildlife habitats and then designing management activities around them. An important concern of all wildlife users is to keep forestry activities to a minimum between mid-May and early July when birds are nesting and ungulates are calving.

Accommodating the environmentalist faction will require substantial land removals for parks (both provincial and federal), ecological reserves, and special wildlife areas. It is better for forest managers to accept this with as much grace as possible and to focus on enhancing yield on the best remaining timber areas while maintaining amenity values and wildlife habitat. It is important that the best management is not only applied but that it is seen to be applied. Too often foresters have failed to publicize their successes. We must make the public in a very real sense our partners in land management, not least because they are insisting upon it.

CONCLUSIONS

The demands of wildlife users to participate in the management of the aspen forest are an important fact of life for foresters. They can be either viewed as a perennial headache or as an exciting challenge to the competence of the forestry profession. These are stirring times!

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UNGULATES AND ASPEN MANAGEMENT

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ABSTRACT

A review of the literature describing wild ungulates and aspen management in North America is presented. Aspen stands and associated vegetation provide food and seasonal cover for moose (*Alces alces*), white-tailed deer (*Odocoileus virginianus*), mule deer (*O. hemionus*) and wapiti or elk (*Cervus elaphus*). Aspen forage is considered high in digestible energy and crude protein relative to other browse species. Clear-cutting and fire are used by wildlife managers to enhance aspen regeneration and provide quality habitat.

INTRODUCTION

Trembling aspen (*Populus tremuloides* Michx.) is the most widely distributed North American tree species, growing in every Canadian province and at least 26 states of the continental USA (Little 1971). The distribution of four wild ungulates: moose, white-tailed deer, mule deer, and elk, are closely associated with the aspen ecotone (Fig. 1). All tend to be forest or forest-edge animals, all can survive on dormant browse, and all are highly regarded for their recreational viewing and hunting values. DeByle and Winokur (1985) have published an extensive review of aspen and wildlife in the western United States. The objective of this paper is to examine the role of aspen in providing ungulate habitat needs and to discuss some management options.

Timmermann, H.R. 1991. Ungulates and aspen management. *In* S. Navratil and P.B. Chapman, editors. Aspen management for the 21st Century. Proceednigs of a symposium held November 20-21, 1990, Edmonton, Alberta. For. Can., Northwest Reg., North. For. Cent. and Poplar Counc. Can., Edmonton, Alberta.

HABITAT NEEDS

Moose

Moose are a species closely linked to northern trees and shrubs of the boreal forest. Best habitats are seral stage forests (up to 20 years) following disturbance by fire, insect damage, blow-down, or logging (Krefting 1974; Franzmann 1978). Moose, a browser, is classified as a concentrate selector; a ruminant that selects a non- or low-fiber diet high in lignin and of easily digestible cell contents (Kay et al. 1980; Hofmann 1985). Habitat needs are summarized by Peterson (1955), Peek (1974), Telfer (1978), Coady (1982), and Timmermann and McNicol (1988). Moose require large daily quantities of forage (18 kg in June for a yearling cow to 51 kg in October for an adult bull) for maintenance and growth (Gasaway and Coady 1974). Several hundred plant species are known to be eaten by moose, but usually not more than 25-30 species are eaten in any one locality (Morrow 1976—cited by Telfer 1978).

Aspen is reported to be one of the top six seasonally preferred terrestrial browse species (Peek et al. 1976; Belovsky and Jordan 1978; McNicol et al. 1980; Thomson and Vukelich 1981; Crete and Jordan 1982; Irwin 1985; Cumming 1987). Winter habitat studies conducted by Welsh et al. (1980) in northeastern Ontario indicated a preference for aspen- and birch-dominated stands as the hardwood component increased up to 80% following logging. Hunt (1976) reported Saskatchewan winter densities of moose were 56% higher in aspen cutovers compared to adjacent uncut areas. Recent forage studies conducted in central Saskatchewan by Terrestrial and Aquatic Environmental Managers (TAEM 1988) estimated that regenerating aspen stands could support up to seven moose per square kilometre, compared to four per square

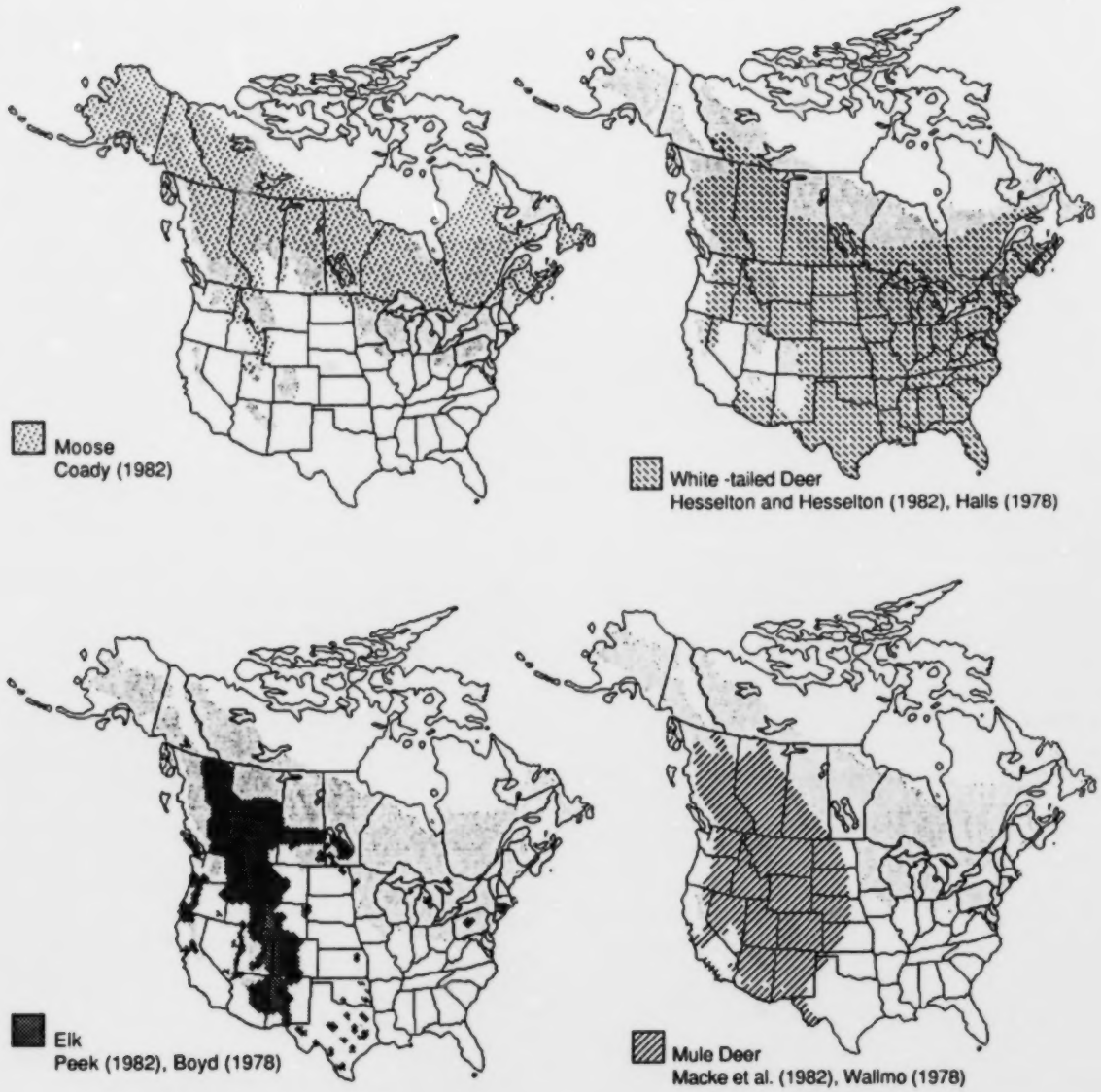

Figure 1. The overlapping range of four North American ungulates and aspen (Little 1971).

kilometre for mixed jack pine (*Pinus banksiana* Lamb.) stands 10 years after cutting. Similarly, they suggested 40- to 80-year-old aspen stands would support three moose per kilometre compared to only 0.1-0.3 moose per kilometre in jack pine-aspen mixed stands of comparable age.

Many of the understory shrubs and forbs in the aspen type are valuable as moose forage, and plant species diversity improves habitat quality (Peek 1974; Oldemeyer et al. 1977; Miquelle and Jordan 1979).

White-tailed Deer

White-tailed deer are the most widely distributed wild ungulate. They are present in 8 of 10 Canadian provinces and 45 of 49 continental states. A northward range extension has occurred in response to agricultural and forestry practices (Hesselton and Hesselton 1982). An extensive review of continental white-tailed deer food and cover requirements is detailed by Halls (1978, 1984). Reviews have also been done specifically for eastern North America (Blouch 1984), western Canada (Wishart 1984), the northern Rocky Mountain states (Peek 1982), and southern Rockies (Evans 1984). Browse is the primary source of food, and aspen is considered important particularly from the lake states and Ontario west to the Rocky Mountains (Blouch 1984; Hesselton and Hesselton 1982). Byelich et al. (1972) considers aspen to be the lake states' leading deer-producing forest type. In western Canada, both the aspen parklands and aspen-dominated boreal forest provide prime deer habitat (Cairns and Telfer 1980; Wishart 1984). Cottonwood (*Populus* sp.) and aspen are preferred in the mountain states as far south as Arizona according to Singer (1979) and McCulloch (1982).

Studies of deer in central Saskatchewan by TAEM (1988) suggest up to 15 deer per square kilometre can be maintained on 10-year-old aspen stands, and six can be maintained per square kilometre in 20-year-old mixed aspen-jack pine forest. The production and nutrient content of aspen understory vegetation provided by a large number of plant species is of particular value to all ungulates (Reynolds 1969; Severson 1982; Crouch 1983).

Mule Deer

Mule deer are common throughout the range of aspen in western North America and are currently distributed in four Canadian provinces and 16 of the western United States (Mackie et al. 1982). Characteristic habitat includes broken and timbered or non-timbered breaks along water courses and adjacent draws (Hamlin 1978; Severson and Carter 1978). Som mule deer are migratory; they spend summers at high elevations within the aspen zone and winters at lower elevations (DeByle 1985). They are classed as intermediate feeders by Hofmann and Stewart (1972) because of their adaptability to a wide range of forage types and phenological conditions. Kufeld et al. (1973) listed 673 species of plants including 202 shrubs and trees eaten by Rocky Mountain mule deer. They reported aspen to be among the top eight preferred browse species, and when available, it was used moderately in winter, spring, and summer. Heavy use of aspen leaf litter in the autumn and early winter has been reported by Julander (1952). Mule deer also consume a variety of understory shrubs and forbs (Collins 1979; Kufeld et al. 1973) and use aspen stands as resting areas throughout summer (Collins and Urness 1983). Habitat needs of mule deer are summarized by Kerr (1979) and Wallmo (1978, 1981).

Elk

Elk, once the most widely distributed members of the deer family (Hall and Kelson 1959) are now largely confined to mountainous areas of the west. Rounds (1981) reported a preference for grasslands or shrublands adjacent to recently disturbed aspen or mixed forest. Kufeld (1973) listed 159 forbs, 59 grasses, and 95 shrubs and trees eaten. Grasses and sedges are the primary summer forage, making up 75% or more of the elk's annual diet according to Boyd (1978) and Gates (1981). Aspen is considered a highly valuable browse species in winter, spring, and autumn (Boyd 1970; Stevens 1974; Nelson and Leege 1982), and aspen communities are preferred over coniferous communities. The aspen understory often provides large quantities of forbs and grasses regarded as high-quality summer and early fall elk food. Kufeld (1973) reported woody species including aspen aver-

aged nearly 27% of the annual diet; whereas in winter, browse may include more than 60% of forage eaten (Gates and Hudson 1983; Nietfeld 1983), including leaf litter (Hobbs et al. 1981). Elk commonly concentrate in high numbers on winter ranges, where they may heavily browse and damage aspen by barking and suppressing growth[1] (Krebill 1972). On summer range they are often well distributed, and use of aspen and associated understory species is considered light (DeByle 1985). The ecology and management of elk are detailed in a comprehensive review by Murie (1951), Boyd (1978), Boyce and Hayden-Wing (1979), and Thomas and Toweill (1982).

ASPEN FORAGE QUALITY

Digestible energy and crude protein are regarded as the most important nutrients supplied by range forage (Moen 1973; Oldemeyer 1974; Wallmo et al. 1977). A Saskatchewan study reported aspen to have similar or higher crude protein and total digestible nutrient levels (12.4 and 34.8% seasonal average respectively) when compared to five other preferred moose browse species (Stewart et al. 1977).

Digestibility of aspen forage in various ungulate studies is summarized in Table 1. Dry-matter digestibilities were higher for foliage (29.6-72.7%) during the green period than for twigs (27.1-51.3%) after leaf abscission. In autumn, moose feed selectively on residual green aspen leaves protected from frosts, which remain up to 60% digestible (Renecker and Hudson 1988). Leaf litter, which accumulates at rates up to 2400 kg/ha in aspen forests, can be an important autumn, winter, and early spring forage because it is more digestible than woody browse (Renecker and Hudson 1986). Aspen had the highest percent digestibility (39-47%) among all winter browse species selected by elk in Colorado (Hobbs et al. 1981). During late winter and early spring, ungulates occasionally strip bark from aspen. A shortage of available forage and relatively good bark digestibility related to a high-sugar transfer rate are believed responsible (Baker et al. 1975; Renecker and Hudson 1985; Miquelle and Van Ballenberghe 1989).

Plant protein levels are higher in summer than winter (Oldemeyer et al. 1977; Renecker 1987), and there is more protein in green leafy foliage than there is in twigs or bark. Levels occasionally approach or exceed 20% in some aspen stands during early stages of growth (Tew 1970; Renecker and Hudson 1988) and then decline over summer to ±11% prior to leaf fall (Table 1). Levels in woody twigs are about half those found in green foliage, and they generally fall between 5% and 8% in winter. Living and fallen leaves remain consistently higher in digestibility and protein than twigs and are valuable for a considerable time (Julander 1937; Renecker and Hudson 1988).

Plant protein provides nitrogen required for growth, reproduction, lactation, and body maintenance (Morrison 1954; Dietz 1970). Schwartz et al. (1987) demonstrated that Alaskan moose require a minimum dietary crude protein level of 6.8% ± 0.8% just to meet maintenance requirements. Energy needed for new tissue production (i.e., pregnant cows, growing calves) may triple or quadruple energy needs. For optimal growth of white-tails, forage should contain at least 13-17% protein according to French et al. (1955) and Verme and Ullrey (1972).

In spring and early summer forage, quality in aspen-dominated habitats remains high (≥12% protein) (Ullrey et al. 1967; Renecker and Hudson 1985). After leaf fall and over winter, ungulates reduce their dietary intake in response to a decrease in forage digestibility and crude protein. Nutritional levels in woody browse are only marginally adequate for body maintenance requirements, and a negative energy balance usually leads to over-winter weight loss.

Recently, Schwartz et al. (1980) developed a formulated moose ration containing 11.8% crude protein with a 64% dry matter digestibility. The use of aspen sawdust as the primary constituent is believed to be the major reason for the formulation's success.

ASPEN COVER USE

Aspen stands and associated conifer patches, if available, provide ungulates with important

[1]Personal communication, October 1990, from R.J. Mackie, Department of Biology, Montana State University, Bozeman, Montana.

Table 1. Percent crude protein and digestibility in aspen vegetation reported for 14 ungulate forage studies

Jurisdiction	Time collected	Plant part[a]	Crude protein[b] (%)	Dry matter digestibility (%)	Source
Utah	June	L	17.0	--	Tew 1970
Saskatchewan	June	L	36.8	44.7	Stewart et al. 1977
Alberta	Late spring	L	22.1	55.7	Renecker and Hudson 1988
Utah	July	L	13.2	--	Tew 1970
Alaska	July	L	13.8	56.8	Oldemeyer et al. 1977
Idaho	July	L	22.6	72.7	Canon et al. 1987
Colorado	Summer	L	≤17.0	--	Short et al. 1966
Alaska	July	T	8.3	64.1	Oldemeyer et al. 1977
Maine	August	L	13.0	--	Abell and Gilbert 1974
Saskatchewan	July	L	19.8	30.6	Stewart et al. 1977
Maine	August	T	4.9	--	Abell and Gilbert 1974
Idaho	August	L	16.8	56.9	Canon et al. 1987
Utah	September	T	11.8	--	Tew 1970
Saskatchewan	September	L	10.4	29.6	Stewart et al. 1977
Idaho	September	L	13.4	54.0	Canon et al. 1987
Alberta	Autumn	L	12.8	51.3	Renecker and Hudson 1988
Alberta	Autumn	T	8.6	44.3	Renecker and Hudson 1988
Saskatchewan	October	T	8.7	27.1	Stewart et al. 1977
Alberta	November	T	8.5	--	Wishart 1984
Saskatchewan	December	T	8.1	31.5	Stewart et al. 1977
Maine	December	T	7.2	--	Abell and Gilbert 1974
Colorado	Winter	T	6 to 7	--	Short et al. 1966
British Columbia	Winter	T	7.1	--	Cowan et al. 1950
Alaska	Winter	T	6.8	--	Oldemeyer 1974
Wyoming	Winter	B	6.9	--	Houston 1968
British Columbia	Winter	B	<12.7	--	Cowan et al. 1950
Colorado	Winter	T	5.6	44.0	Hobbs et al. 1981
Alberta	January	T	8.5	--	Wishart 1984
Alberta	February	T	8.1	--	Wishart 1984
Saskatchewan	May	T	8.1	34.0	Stewart et al. 1977
Alberta	March	T	8.1	--	Wishart 1984
Alberta	Early spring	T	7.1	45.4	Renecker and Hudson 1988
Alaska	Formulated ration	T	11.8	64.0	Schwartz et al. 1980

[a]L = leaves; T = twigs; B = bark.
[b]In percent dry weight.

seasonal cover needs. Thermal cover provided by overstory vegetation gives protection from weather and sun, and security cover is used for hiding or escaping from predators and humans (Black et al. 1976). Peek et al. (1976) reported high use by moose of moderately stocked mature aspen and white birch (*Betula papyrifera* Marsh.) in summer. Stands of 9-15 m were used more frequently than other height classes. Moose studied by Mytton and Keith (1981) in central Alberta used aspen islands within muskegs during summer months. Renecker and Hudson (1986) reported heat stress occurred at 14-20°C, forcing moose to seek cool cover types. Thermal cover provided by pole-sized aspen stands or larger are believed important for elk (Gates and Hudson 1981; Peek et al. 1982; Collins and Urness 1983). Trees in patches 12 m or higher with a crown closure of at least 70% provide thermal cover in the blue mountains of Oregon and Washington (Thomas 1979). Elk commonly forage within 90 m of cover and prefer to bed in or near cover after feeding (Collins 1979). DeByle (1985) suggested aspen stands also provide critical cover and forage for cow elk and newborn calves. Stormer and Bauer (1980) speculated that Michigan white-tailed deer spend more time in mature aspen in summer, perhaps because of lower temperatures and fewer biting insects. Aspen communities on the western deer range are heavily used in summer and autumn when aspen and associated deciduous shrubs are in full leaf and both thermal and hiding cover are abundant (Leckenby et al. 1982; TAEM 1988). During this period, Collins and Urness (1983) reported deer commonly bed down in the aspen forest.

In autumn, security cover is essential for wild ungulates during the hunting season. Young, dense stands of aspen regeneration, mixed aspen stands, and those with a dense understory are often heavily used. With autumn leaf abscission, the cover value of aspen decreases markedly, and mixedwood stand edges become more important in providing ready access to escape cover near forage. Hunt (1976) found moose moved further from cover in severe Saskatchewan winters, avoiding young 0- to 4-year-old aspen cutover in favor of 5- to 10-year-old stands. Novak (1978) reported that mature aspen stands allow solar radiation to reach the forest floor during a longer period of day while still providing some wind shelter under moderate snow conditions. In the aspen parklands of the west, aspen and associated vegetation often provide the only cover available to ungulates during all seasons (TAEM 1988).

ASPEN MANAGEMENT

Aspen regenerates promptly after logging or fire (Brinkman and Roe 1975). The production of both aspen suckers and understory biomass peaks up to 5 years after a disturbance, and production of ungulate forage continues for about 15 more years (Spencer and Hakala 1964; Wolff and Zasada 1979; Bartos and Mueggler 1982; Bartos et al. 1983). Forest disturbance should be managed to maintain a diversity of vegetation types and age classes within the animals' home range (Davidson et al. 1988).

The size of burns or clear-cuts recommended for moose varies from 15 to 130 hectares, with 100 hectares suggested as optimal (Peek et al. 1976; Parker and Morton 1978; Ontario Ministry of Natural Resources 1988). In mixedwood stands, accessible aspen browse should be interspersed with suitable adjacent conifer cover to minimize winter metabolic demands and energy expenditures (Coady 1974). Edge-to-cover distances should not exceed 400 m (Ontario Ministry of Natural Resources 1988; Manitoba Natural Resources 1989), and cut blocks with irregular boundaries will increase edge. A minimum of 50% conifer cover should be retained on critical winter habitat (Ontario Ministry of Natural Resources 1986). Rotation age of 50-60 years in aspen and 40-50 years in mixed aspen stands should maximize benefits of food and cover. One-third to one-half of the planning area should be maintained in stands less than 20 years of age (TAEM 1988).

White-tailed deer habitat guidelines in aspen include providing for an array of aspen age classes by cutting or burning in 4- to 16-ha patches in a 40- to 80-year rotation (Rutske 1969; Bartos and Mueggler 1982; Manitoba Natural Resources 1989). Voigt (1990) recommends a maximum distance to shelter of 100 m. Early spring burning is best according to Gullion (1984), one or two seasons after cutting to promote suckering and reduce slash. Byelich et al. (1972) recommends cutting an area of ±100 ha on a 10-year rotation, removing 25% each time.

Telfer (1974) suggests small patches and strips are more beneficial than large openings. Graham et al. (1963) linked recommended cut size to deer densities. With deer densities of 4-9/km^2, cuts should be small (8 ha). As densities double, so should cut sizes. They believed deer densities of >19/km^2 will cause total destruction of sucker stands due to the ability of deer to browse ≤1.5 m (Mueggler and Bartos 1977). Cuttings near known deer yards can benefit deer during winter, but no more than 50% cover should be removed (Rutske 1969; Manitoba Natural Resources 1989). In Saskatchewan, TAEM (1988) recommended cuts <50 ha close to mature forest stands to provide accessible thermal and escape cover. Michigan improved 55 603 ha of deer habitat between 1972 and 1987[2]. Treatments in aspen stands included prescribed burning after cutting, clear-cutting upland brush, and the manual removal of residual aspen. During this 15-year period, Michigan deer numbers tripled, and the long term impacts of declining aspen range were corrected.

Mule deer are more selective of plant species than elk and cannot digest some forages as efficiently (Collins and Urness 1983). Several methods have been proposed to manage aspen stands to enhance western mule deer habitat (Patton and Avant 1970; Hooven 1973; Gruell and Loope 1974; Hilton and Bailey 1974; Jones 1975). Most authors advocate occasional use of cutting, fire, or herbicides to create openings (12-24 ha) in late successional or climax stands. More conservative approaches (Alexander 1974) suggest clear-cutting one sixth of the management unit every 20 years in openings 100-150 m wide, averaging 2 ha. Collins and Urness (1983) cautioned that clear-cutting of aspen may only be beneficial when range conditions are more restrictive. They found aspen cuts were used at about the same level as uncut aspen, and mule deer better liked resting in aspen stands than did elk. Edgerton (1972) suggested information on size, shape, and distribution of cutting units is incomplete.

Optimal elk habitat recommended by Thomas (1979) is a mix of 60% of the land area in forage production and the remainder in cover. He suggests patches of 10-26 ha will provide adequate security or hiding cover. Cut blocks should have irregular edges. Blocks should be designed to provide cover within 200 m of any location and limit line of sight to under 400 m (Alberta Forest Service 1986; Manitoba Natural Resources 1989). Lyon and Ward (1982) speculatively estimated that openings, forage areas, and cover areas in the range of 12-32 ha satisfy the biological needs of elk on summer range. Heavy aspen browsing (>50%), according to Patton and Jones (1977), can lead to a decrease in stand density and the complete elimination of aspen from some sites. Olmested (1977) recommends a 20- to 30-year rotation for browse production.

Elk have been forced to vacate aspen stands in favor of agricultural fields in some areas as grass meadows are replaced by aspen. Prescribed burning, cutting, or bulldozing aspen stands in Manitoba's Duck Mountains are helping to re-establish grassy openings 15-25 ha in size[3].

CONCLUSION

In summary, as the demand for aspen and recreational use of land increases, resource managers will need to become more aware of a wide array of often conflicting objectives and issues. Examples include conversion of aspen and mixedwood stands to conifers employing postcut mechanical scarification and herbicide application. Management prescriptions that maintain or enhance the aspen type to benefit ungulates have been developed. Few, however, have been field tested or verified. Our future challenge through adaptive management is to test and further refine these prescriptions to meet specific regional conditions and objectives. A wide variety of other wildlife species can also benefit from a more-integrated multi-purpose forest management approach.

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[2]Personal communication, November 1990, from H. Hill, Wildlife Division, Michigan Department of Natural Resources, Lansing, Michigan.

[3]Personal communication, October 1990, from U.F.J. Crichton, Manitoba Department of Natural Resources, Winnipeg, Manitoba.

ACKNOWLEDGMENTS

The author is grateful to Roy Klein, Bill Dalton, and John McNicol of the Ontario Ministry of Natural Resources, Thunder Bay; Ed Telfer, Canadian Wildlife Service, Edmonton; and Lyle Renecker, University of Alaska, Fairbanks, for reviewing the manuscript and making helpful suggestions.

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INTEGRATED RESOURCE MANAGEMENT: TIMBER AND WILDLIFE IN ASPEN ECOSYSTEMS

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ABSTRACT

Integrated Resource Management (IRM) with planning approaches based on ecosystem inventories and functions can be used to integrate management of timber and wildlife in aspen ecosystems. Appropriate IRM strategies, compared to existing processes, offer better opportunities to reach balanced decisions.

A QUICK HISTORY OF IRM

Integrated resource management (IRM) is supported by most people interested in the management of resources, particularly forest resources. Integrated resource management means different things to different people, however. In the past, we called it "multiple use" and manufactured generalities that became bibles of rhetoric and implementation. Some of these included "good timber management is good wildlife management" and "increasing habitat diversity is a major objective of habitat management."

In reality, we were operating under a system designed to extract timber. Until approximately the 1950s, we were not aiming for the sustainable use of timber, let alone other resource values. Since then, most timber management systems have evolved to a level of cutting that is probably sustainable in terms of timber alone. The science of timber supply modeling has progressed, but we still tend to push estimates as high as possible and build processing facilities with demands mandating maintenance or an increase in annual allowable cut.

We now have an entrenched system of timber management plans with constraints built in for other resources. As the single most powerful economic piece of the pie, King Timber still rules, and everything else takes a back seat. But as more emphasis is placed on other forest uses, we have become very good at constraint. We have regulation and guideline proliferation and ever-increasing demands for more. In this sense, IRM has come to mean "as much as possible of everything, as long as *I* get what *I* want." We battle over competing agendas from our bastions of bias, never considering what we really mean by IRM.

Until about 25 years ago, wildlife biologists dealing with timber management proposals were mainly interested in game species. Even today, most guidelines and regulations in Canada emphasize big game. In the United States, vertebrate diversity approaches (Thomas 1979; U.S. Fish and Wildlife Service 1980, 1981; Sveringhaus 1981; Salwasser et al. 1984) were developed soon after the National Forest Act of 1976 (16 USC 1601, Regulation 36 CFR 219.19) directed the U.S. Forest service "... to maintain viable populations of existing native and desired non-native vertebrate species in the planning area."

Interest in conservation biology, particularly for endangered species such as the spotted owl (Shaffer 1985) has continued to spur developments in the U.S. Managers everywhere are now emphasizing biodiversity, the total diversity of life, managed with ecosystem approaches (Salwasser and Tappeiner 1981).

A major impediment to IRM has been the separation of management responsibilities and benefits. Forest companies are in business to make a profit from trees, and society benefits from this business. Integrated Resource Management often means a cost to industry with the

Bonar, R.L. 1991. Integrated resource management: Timber and wildlife in aspen ecosystems. *In* S. Navratil and P.B. Chapman, editors. Aspen management for the 21st Century. Proceedings of a symposium held November 20-21, Edmonton, Alberta. For. Can., Northwest Reg., Northwest Reg., North. For. Cent. and Poplar Counc. Can., Edmonton, Alberta.

benefits going elsewhere. Governments are faced with the same dilemma: it is not easy to balance demands such as "maximize forest industry benefits" and "maintain biodiversity."

Until fairly recently, most of this did not apply to aspen ecosystems. With few exceptions, all we wanted to do with aspen was get rid of it. But now aspen is an economic development opportunity. In this paper, I will explore some of the opportunities to manage aspen and wildlife habitat as part of an IRM system.

"REAL" INTEGRATED RESOURCE MANAGEMENT

Integrated Resource Management can be described as the coordinated management of multiple resources, with general goals and specific objectives for each component of the management system. It has four basic components: inventory, planning, implementation, and monitoring for feedback. All must be coordinated by resource managers to derive a system based on adaptive management (Walters 1986).

Traditionally, timber and wildlife information was collected separately; foresters counted trees, and biologists counted habitat and wildlife. The trend is toward more-integrated inventories. For example, the new Alberta Collective Vegetation Inventory Standards were designed to provide information useful to both groups. A step above this is inventory based on ecosystem classification and function (e.g., Jones et al. 1983; Corns and Annas 1986).

Even more importantly, we now have geographic information systems (GISs) and other computer technology to manage inventory and planning systems. Commonly understood inventories and efficient user tools are essential to IRM. They provide the basis for a cooperative management planning process.

As recent events will attest, Canada is not immune to events south of the 49th parallel. Ironically, we keep coming back to IRM, which might have helped if we had only listened to Aldo Leopold (1949). To paraphrase, Leopold provided the basis for IRM: the first rule of intelligent tinkering is to keep all of the parts.

There are a lot of parts. In Canada, there are about 753 species of mammals, birds, reptiles, and amphibians (Banfield 1977; Cook 1984; Godfrey 1986). Depending on location and area, 250-350 of these species inhabit forested lands where aspen is present. Add untold species of plants, insects, fungi, etc., and the diversity becomes so great as to be almost incomprehensible.

To keep all of the parts, we need to know what the parts are and what our actions will do to them. And most importantly, we need to decide what to *do* with the parts. How much do we want? This applies equally to aspen trees and the multiples of other components of aspen ecosystems, including wildlife and wildlife habitat. We need understandings of ecosystem structure and function in both natural and managed circumstances, and we need a process to predict the impacts of management decisions.

To be effective, planning approaches that intend to deal with this diversity must go beyond guidelines applied to timber management plans. For example, the Ontario moose guidelines (Ontario Ministry of Natural Resources 1988) are intended to also support the habitat requirements of 70% of other wildlife species in an area. The other 30% of species are covered by separate guidelines. Application of multiple sets of guidelines is inefficient at best, and problems still occur because there are no quantified objectives.

There are two basic ways to solve this functional problem. One is to design guidelines to manage biodiversity, and the other is to model supply of ecosystems or their components. Either may be used successfully, alone or in combination, but only if monitoring programs tied to inventory and management decisions are employed to calibrate and audit progress.

Modeling approaches (e.g., Bonar et al. 1990; New Brunswick Fish and Wildlife Branch 1990) offer the additional advantages of predicting results and defining specific objectives. These allow managers using models tied to common inventory bases to finally decide how much is enough. There may still be disagreement over needs and wants, but at least negotiations can use the same language and information.

Once goals and objectives are in place, they must be implemented. As we learn more about the complexity and function of natural systems, we learn more about options and flexibility. The single most important thing to keep in mind is an old cliché: do not put all the eggs in one basket. Try different methods and use the ones that prove the most effective, and keep looking for better ones. Do not assume natural processes can be manipulated at will to meet management wants. Working *with* nature offers much better chances for success.

The final piece of a complete IRM system is an effective monitoring and feedback program. The results of management decisions must be audited and returned to the original plan in order to make improvements in the future. This process also identifies problems and offers a means to incorporate new priorities and information.

I have only touched on a few highlights of IRM for timber and wildlife. Those interested in more detail could start with *Wildlife, forests, and forestry: Principles of managing forests for biological diversity* by Malcom Hunter (1990).

IRM: TIMBER *AND* WILDLIFE

To my knowledge, there are no wildlife species in aspen ecosystems that are totally incompatible with timber management. Some would be in trouble, however, if we managed only for timber benefits, with short rotations and silvicultural shortcuts. Conversely, many species can be expected to show favorable responses to timber management.

Species such as ruffed grouse (*Bonasa umbellus*) and ovenbird (*Seiurus aurocapillus*) are among the few that can be considered aspen obligates, or species that depend on aspen in boreal regions. Co-management of aspen and these species would not be difficult, because these birds do not depend on particular features that cannot be found in managed forests.

Problems arise if management proposes removing particular ecosystems or stages of ecosystems from forest landscapes. For example, there are some 50 species of wildlife that either make or use cavities in trees in aspen ecosystems. If rotations are kept short, and no decadent or overmature aspen trees are allowed, the supply of potential cavity trees will greatly decline. This could be mitigated by options such as 1) allowing a percentage of stands to pass through natural succession to conifer species without removing aspen at rotation age; 2) leaving defective or cull trees in clear-cuts, or using other silvicultural systems, to supply potential cavity trees; and 3) managing the amount and distribution of buffers or non-harvested areas to supply cavity trees.

Opportunities also arise. For example, habitat for ruffed grouse and many other species can be expected to increase as aspen forests are shifted towards younger successional stages. The amount of increase can be adjusted by planning sequence, size, and configuration of aspen cutting.

SUMMARY

Integrated Resource Management offers real opportunities for sustainable use of the aspen resource based on management of aspen ecosystems. It should be possible to comanage for timber and wildlife habitat, making balanced resource decisions. Resource managers must avoid the never-ending trap of regulations and reaction (Bonar 1989) and find ways to provide a balanced mix of forest benefits, including timber and wildlife.

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PUBLIC CONCERNS: SEEING THE FOREST AS WELL AS THE TREES

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ABSTRACT

Some members of the public are deeply concerned about the haste, lack of planning, tunnel vision, lack of public input, disregard of the findings of scientific panels, disrespect for native land claims, and negative effects of forest denudation on erosion, water quality, aesthetics, wildlife, tourism, and wilderness values, that have accompanied the rush to turn aspen forests into export pulp. Many concerns go back at least as far as 1978, yet Alberta Forestry, Lands and Wildlife continues to ignore them.

INTRODUCTION

For those who don't know me, I am a zoologist. My subdiscipline is animal ecology, specifically, population ecology of mammals. As a candidate for the Master's degree, however, I took part in studies of Lake Athabasca and Great Slave Lake. Our party studied the physical features of the lakes and their waters, plankton, benthic fauna, and fish. On the basis of those studies, rules and quotas for fish harvesting were recommended to regulating authorities. The Great Slave Lake quota still stands as far as I am aware. Later, I was a wildlife biologist for 12 years—nine in the Northwest Territories and three in Yukon. The basis of my Ph.D. dissertation was a study of bison in Wood Buffalo National Park, with emphasis on the disease problem. Following my time in the north, I taught zoology, wildlife management, and general environmental courses at the University of Alberta for 26 years. During that time, virtually all of my research, and that of most of my graduate students, was done in the Northwest Territories.

I tell you these things to indicate that I have been involved with the commercial use of renewable natural resources. I have no aversion to commercial fishing, or to trapping, or to harvesting timber, provided that all such activities are done in an ecologically and environmentally sound way, based on good scientific studies and reliable information. In my estimation, the hasty push to exploit the aspen forests does not meet these criteria.

What is happening in Alberta reminds me of what is happening in third world countries. They see that there were no environmental constraints during the course of "development" in the so-called "developed" world, and they resent any suggestion that they should not bring in foreign multinationals to exploit their resources, regardless of the environmental cost to themselves and the planet. Alberta sees that some of the other provinces have apparently benefited from exploitation of their forests, mainly by foreign multinationals, and now Alberta wants its turn. Instead of learning from the mistakes of others (British Columbia could tell us something about clear-cuts and mud slides, for example), we seem to be wedded to the Paul Bunyan syndrome, but with a feller-buncher instead of an axe and an ox.

I have been asked to address "public concerns," but what, or who, is the public that I am to represent? A part of the public unreservedly favors expanded exploitation of the forests in the name of economic growth and diversification. Another part is neutral or indifferent and largely unconcerned. They are naive enough to think either that large forestry enterprises would never do anything wrong, or, if they did, the

Fuller, W.A. 1991. Public concerns: seeing the forest as well as the trees. *In* S. Navratil and P.B. Chapman, editors. Aspen management for the 21st century. Proceedings of a symposium held November 20-21, 1990, Edmonton, Alberta. For. Can., Northwest Reg., North. For. Cent. and Poplar Counc. Can., Edmonton, Alberta.

government would hold them accountable. To that view, I can only reply, "There is no accounting for what some people think." A third category believes "there is no use fighting city hall"—i.e., the government will do what it wants anyway. I belong to a component of the public that is not prepared to accept the unsupported pronouncements of industry and government that neither the forests nor the environment as a whole will suffer from the massive schemes that have been announced and those that are still to come. I will try to deal with some of the concerns of this last group of people.

In the nearly 2 years since Premier Getty announced approval-in-principle for the Alberta-Pacific mill, the public I represent has been insulted, denied access to information, refused consideration of reasonable requests for more time, denied any input into Forest Management Agreements and integrated resource planning, and generally treated as if we, the public, are not part owner of the resource in question, and therefore have no business expressing concern.

My job has been made much easier by publication of *Forest management in Alberta: Report of the expert review panel* (Expert panel on forest management in Alberta 1990), which I will refer to as the Dancik report, or simply Dancik. Major public concerns are listed in Sec. 2.4 on pages 7 and 8 of the report.

TUNNEL VISION

For at least a couple of decades, in my experience, Alberta Forestry, Lands and Wildlife (which has the appropriate acronym, FLAW) has been afflicted with a severe case of tunnel vision. The reasons for this affliction do not need to concern us, though I believe they are fairly obvious; it is sufficient to note that fiber is virtually the only desired product from the aspen forest. Concomitantly, the Alberta Forest Service (AFS) has come to dominate the other two divisions in the department. In the case of Fish and Wildlife, the Dancik report noted

> By almost any measure, the division has been understaffed and underfunded; new biological staff must be added and funding increased (Sec. 3.1, Page 12).

Furthermore, Fish and Wildlife has little say in the early planning stages and the negotiations concerning Forest Management Agreements (FMAs). According to the Dancik report:

> Although the concept of integrated resource management is in place and the government's referral system permits Fish and Wildlife to make recommendations concerning FMAs, this input remains primarily a reactive process in which Fish and Wildlife attempts to minimize the impacts of forest activities on fish and wildlife *after* the Alberta Forest Service has done the planning and developed the ground rules. ... the AFS decides whether the recommendations will be included... (emphasis in original) (Sec. 7.6, Page 65).

The Public Lands Division, similarly, has been unable to do its work. Enormous areas have been dedicated to exploitation before integrated resource planning (IRP) has been completed; in some cases before planning has even begun. If the plans are complete for the northeastern region at this very moment, they are a well-kept secret.

Alberta Forestry, Lands and Wildlife, more particularly the AFS, is in a partnership with industry, not the people, who are the real owners of the forest resource.

LACK OF ADVANCED PLANNING

At least as far back as 1977, a consultant's report (Jones 1977) suggested where pulp mills might be located to use the (largely) aspen forests of northern Alberta. In the last few months we learned that Jaakko Pöyry (1983) had recommended a large bleach kraft pulp mill in the general region of Athabasca-Lac La Biche in 1983. Given so much warning, it is reasonable to suppose that FLAW would have been busy for the last decade planning for the projects that are now upon us. It is now clear, however, that such was not the case. Some examples of missed opportunities follow.

Neglect of Research

I believe it is a truism that good planning requires good information. Research is not the only way to obtain information, but few would question that it is a powerful tool. During the years leading up to the announcement of large-scale forest development, FLAW not only failed to get the information required for adequate planning, but it disbanded both the fisheries and the wildlife research sections. (Apparently, a small fisheries research section was reconstituted, quietly, in 1989.)

The Dancik report takes FLAW to task for the poor quality of its information base and its neglect of research. For example, in Sec. 9.2, Page 94, we read

> In many places in this report, the panel has alluded to the lack of information about particular topics and the need for further research.

I deal with many of the deficiencies identified by Dancik in the next five sections of this paper. Dancik goes on to say:

> These and many other questions about forest resources (including wildlife, fisheries, and recreation) must be addressed, yet *there has been less than token funding from the province for such research*. The recent expansion of the forest sector has created further demands on the research community, but *there has been no commitment of new dollars to this needed research*. (emphasis added) (Sec. 9.2, Page 95).

Forestry, Lands and Wildlife claims that income from the forests will replace the income formerly generated by the petroleum industry. If that is true, surely money can be found to do it right—that is, on the basis of comprehensive, sound research.

Timber

Since the trees that yield the fiber are what it is all about, one expects that at least for the timber resource we would have a good inventory. Right? Well, maybe not. The Dancik report expressed some reservations. For example:

> The public is concerned about the reliability of forest inventories and the preparation of the management plan itself. A reliable estimate of the volume and growth of forest stands is fundamental to the accurate definition of sustainable harvest levels for any FMA ... (Sec. 5, Page 21).

Here is what the report has to say concerning hardwoods in particular:

> In the early years, no attempt was made to distinguish hardwood species, because hardwoods were viewed as weed species. ... the Phase 3 Inventory still does not differentiate between hardwood species with any precision (Sec 5.1, Page 22).

Need I remind anyone in this audience that aspen is a hardwood? I do not know a wildlife manager who would be bold enough to manage wolves on the basis of an inventory that lumped wolves with other canids such as coyotes and foxes.

Wildlife

When it comes to wildlife, what sort of inventory do we have? It is probably best described as totally inadequate. Here is what the Dancik panel wrote:

> The report [Alberta Fish and Wildlife 1987] pointed out that the division has never had comprehensive substantive inventory planning, comparable to the Alberta Forest Service's phased forest inventory programs or Alberta Agriculture's soil surveys. Most existing resource information available to the division is in widely scattered, variable-format, manual files and maps that are cumbersome and time consuming to access and maintain (Sec. 5.1, Page 23).

Furthermore,

> There is also no definitive plan to ensure that an adequate inventory

> tailored to the wildlife management goals of game and non-game wildlife species and their habitats will be done to complement the timber inventory before forest management plans are approved (Sec. 5.1, Page 24).

Inventories, of course, are merely the first step. Extensive clear-cut logging will turn enormous areas into a series of disconnected ecological islands separated by a sea of denuded or regenerating unsatisfactory habitat. If we are not to lose species diversity under those conditions we should be planning the harvest regime according to the precepts of island biogeography. Ecologists have devoted much attention, both theoretical and empirical, to those precepts, but the entire concept appears to be unknown in the upper levels of Alberta Forestry, Lands and Wildlife.

Fisheries

Fisheries are no better off. In fact, their situation may be worse. Their habitats are threatened by the effects of logging as described in the Dancik report:

> ... fisheries biologists identified their major concerns about logging in general as: sedimentation, physical deterioration of stream banks and channels, increases in nutrient loads and water temperature, barriers to fish passage, loss of vegetation on stream banks, and the effects of widespread forest removal on stream flow. ... Alberta Fish and Wildlife is not given the opportunity to conduct fisheries inventories or management-oriented research before FMAs are signed (Sec. 6.6, Page 53).

Most if not all of the effects listed were known to fisheries biologists when I was working with fish, which was not last year, or in the last decade, or even in the last half of this century. The potential problems have been well known for a very long time. The only conclusion that one can draw is that FLAW couldn't care less, as the saying goes, about the fish resource.

Fish and their habitats are also threatened by noxious effluents and high levels of biochemical oxygen demand, especially during low winter flows, from facilities such as pulp mills. At the time of the Alberta-Pacific environmental impact assessmment hearings it became known that no one knew for sure what species of fish lived in the Athabasca River and its tributaries from well above Athabasca to below Grand Rapids. A list of species is about the most elementary data one can think of, yet FLAW did not take the trouble to obtain even that. Nothing, I think, could reveal more starkly the way in which FLAW has been derelict in its duty to protect the resources entrusted to its care. How do you protect something when you don't know you have it?

Rare, Endangered, and Threatened Species

Maintenance of ecological and genetic diversity is much talked about in ecological circles these days, but it seems to be a non-concept at FLAW. Maintenance of diversity implies concern for rare, endangered, or threatened species whether they be plants or animals. The Fish and Wildlife division has made an attempt to give them some protection, as the following quotation from the Dancik report reveals, but their efforts have been thwarted.

> The 1989 draft, *Strategic plan for management of Alberta's wildlife*, provides goals, status, and management (objectives, concerns, strategies, priorities by region) for endangered, threatened, and vulnerable species. ... Fish and Wildlife has been unable to implement the management objectives and strategies recommended ... because the plan has not received final approval and because there are insufficient biological staff and funding to adequately implement the plan (Sec. 7.7, Page 66).

Reservations for Various Public Uses

In a properly planned development program, reserves for public use and enjoyment, or otherwise in the public interest, would have been established by statute before enormous areas were signed away. Why this was not done in Alberta is a matter for conjecture, but it reflects badly on the professionalism of the people who advise the minister, on the minister himself, and

on the forest industry, which puts its own welfare before that of the public.

Wilderness

As far back as the 1960s, biologists were urging the provincial government to identify and reserve wilderness areas in the northern half of the province. The answer was always, "We don't need formal reserves, it's all wilderness anyway." In 1979, the Environment Council of Alberta recommended a boreal wilderness in its report on forestry activities. At that time, there was still plenty of uncommitted land available. Now that a major part of the boreal forest has been committed to long-term, exploitative use, the opportunity to establish a meaningful wilderness area is very nearly, if not entirely, lost. In the words of the Dancik report:

> The panel supports the recommendation made by the Environment Council of Alberta (1979) for a boreal wilderness area; it regrets that candidate wilderness and park areas were not set aside before new boreal forest developments were proposed or established (Sec. 6.4, Page 48).

Ecological Reserves

The International Biological Program, to which Canada was a signatory, had a section called Conservation of Terrestrial Communities, CT for short. Between 1965 and 1974, botanists, zoologists, and others drew up lists of candidate areas in each biogeographic region in every province and both territories for protection as ecological reserves. In its final report the Alberta panel urged that several large reserves be established in the northern half of the province *before* the land was all allocated to other uses. The plea fell on deaf ears.

It was not until 1987 that Alberta finally began to enshrine a few areas as reserves, but representation of forest ecosystems is inadequate, as the following quotation reveals:

> There are currently 11 ecological reserves in Alberta that have been established since 1987. ... They do not include a representative sample of forest ecosystems, and there are only two reserves within the north and northeast sections of the province (Sec. 6.4, Page 48).

Since the above was written, a twelfth reserve has been announced at Rumsey, which does nothing to alter the situation in the boreal region.

Old Growth

It does not require a lot of ecological smarts to recognize the value of old growth to many denizens of the forest, both plant and animal. An administration that was truly concerned about all the resources of the forest, that is, one that does not suffer from tunnel vision, would have planned for the management of old growth from the outset. Why is it that the AFS still sees old growth as a deadly danger to the whole forest that must be eliminated as the first step in forest "management" as reported by Dancik?

> There is at present no policy designed explicitly for reserving old-growth forest ecosystems in Alberta. Under the present policy ... *removal of overmature timber is given priority* and the reservation of old growth is incidental during the process of "netting out" areas ... during management planning (emphasis added) (Sec. 6.5, Page 51).

The Dancik report has several other important things to say about old growth. First of all, it recognizes that old growth is "of great public concern" (Page 32). In view of the deficiencies in policy and planning, the problem now is to try to get something back after it has been given away in a secret, legally binding deal.

> The present system of trying to accommodate unanticipated requirements for blocks of mature and old-growth forest after FMAs have been approved is ineffective (Sec. 5.3, Page 32).

The solution to the problem is equally obvious, as the report goes on to say.

> If a reserve area ... were included within each FMA, it would act as a bank from which annual allowable cut land base could be allocated to replace deficiencies ... (Sec. 5.3, Page 32).

Some may think that the "incidental" reserves of old growth referred to above provide a satisfactory answer to the problem, but the Dancik report disagrees, as would most ecologists.

> Such reserves tend to be fragmented and not specifically selected to represent intact ecosystems or to address particular attributes of old-growth forest ecosystems. Such reserves are also subject to salvage harvesting under existing forest management policies (Sec. 6.5, Page 51).

The fact that they are subject to salvage harvesting raises the question, "When is a buffer not a buffer?" Obviously, streamsides have no long-term security.

Parks

At one time in the past there was serious talk of a major provincial park in the northern half of the province—something that would rival Kananaskis. It was even referred to as "Kananaskis North." That idea seems to have been quietly dropped. In its place there seems to be a hastily thrown together scheme for a park of sorts southeast of Lac La Biche. From the sketchy reports that I have seen, the proposed Lakeland Park will not rival Kananaskis in physical size, in the size of its budget, or in the whiteness of its sand traps. As I understand it, most of the park would be open to various pursuits that are incompatible with the kinds of values that true parks are meant to preserve.

What Does the Future Hold?

Is there any chance that the current situation with respect to reservations for public use can be rectified? In theory, yes. Where an FMA has already been signed, it is claimed that land base can be removed in exchange for an equivalent timber supply from outside the original boundary of the FMA. Where an FMA has not yet been signed, FLAW could act in the public interest and set aside reserves during the secret negotiations that lead to the final agreement. In recent FMAs, apparently, some 4% is set aside as a reserve. Previously, the figure was 2%, so I suppose some progress has been made, but we are still a long way from the 10% or 12% suggested in the report of the World Commission on Environment and Development (1987).

In practice, FLAW seems quite unlikely to reverse its long-standing policy of tunnel vision in favor of retaining 10% or more public land for the benefit of the public.

Industry, too, could play a role. The Alberta Forest Products Association is now advertising that it is "turning a new leaf." One way in which it could demonstrate its *bona fides* would be to forego its demands for compensation for withdrawals of land base for legitimate public uses. In practice, as demonstrated both in Alberta and most notably in British Columbia, the industry is unlikely to allow altruism to temper its insatiable greed. Under the industry's definition of "sharing" even a ratio of 96 to 4 is too generous a share for the public.

Native Issues

The minister of Alberta Forestry, Lands and Wildlife maintains that an FMA is simply a guarantee of timber rights and not a land deal. Nevertheless, the status of the Crown land incorporated into an FMA changes from unoccupied to occupied, which has serious implications for Alberta's native inhabitants. Treaties gave to the native peoples the right to hunt for food at any time of the year on unoccupied Crown lands, but that right does not hold for occupied Crown lands.

Coupled with this is the intransigence of Canada and Alberta when it comes to settling outstanding land claims, particularly claims of the Lubicon. It is cheap and tawdry behavior to haggle over a few square kilometres of land. Surely the size of the claim is tied to the number of people. Surely the governments do not think that the number of people in the band should be the same now as it was in 1939 when negotiations first began. The delay is not the fault of the Lubicon, and there is no reason that I can conceive of why they should suffer for the stupidity and avarice of people who are

supposed to represent me. I do not see the justice in allowing foreign multinationals access to the disputed territory before the claim is settled in a just and generous manner if the forest industry is indeed to be the savior of the Alberta economy.

PUBLIC INPUT TO DECISIONS

The Dancik report states:

> The public expressed lack of trust in the work conducted by both companies and government agencies as background to the proposed developments. There is obviously a need for greater public participation in the review process, if the public is to overcome its distrust and begin to understand forest management issues (Sec. 9.3, Page 87).

I see four places where the public could have input to forestry decision making. They are dealt with here.

Environmental Impact Assessment

FLAW has resolutely resisted public requests for an environmental impact assessment (EIA) on the forestry, as opposed to the facility, aspect of forest exploitation. One of FLAW's arguments is that an EIA is a snapshot, whereas what is needed is a motion picture. The Dancik report also played down the utility of such EIAs, calling them "comprehensive but superficial" (Page 18); however, forestry practices do influence the kind of forest that we leave to future generations, and they do have immediate effects that go beyond the forests themselves, most notably to water bodies of all kinds.

The landscapes and forests of northern Alberta are similar enough, for the most part, that a single, Class EIA would be sufficient to reveal problems such as soil compaction, soil erosion, and subsequent sedimentation in major rivers, release of heavy metals from soils, altered flow regimes in rivers, post-harvest flooding, reserves for public use, protection of old growth, alternatives to clear-cut logging, use of herbicides, and adequacy of regeneration. All could be addressed in depth, and recommendations could be incorporated into amended ground rules or other policies.

If the existing regulations are adequate they should stand up to scrutiny by the public and an independent panel of experts. If not, they should be amended.

Integrated Resource Planning (IRP)

In a thorough study of forestry law in Alberta, Moen (1990) had this to say about public participation:

> In my view there is a model ... (that) ...reflects both flexibility and the ability of the public to have influence on the decisions of the government. Of significance to the development of a model is the public belief that its views have been seriously considered in an open, visible process (Page 93).

She continues with an extract from the decision of the Federal Court of Appeal in the Rafferty case. Justice Muldoon said

> The important aspect of the public review is that it must be wholly public. It is the antithesis of secret or unpublicized arrangements in these matters of quintessential public interest.

Ms. Moen speaks highly of integrated resource planning (IRP) as a process that "... ensures that all resources and resource users are taken into consideration and that input is obtained not only from government agencies but also from the public and from other interested organizations."

However, she also cautions that in unsettled areas of Alberta:

> Integrated resource planning is not legislated. ... Further, there are no regulations under the Public Lands Act which guide the process to be followed by the Department of Forestry for development of integrated resource plans. ... Without a legislated process, Albertans can not be sure that it will be used (Pages 94-95).

At a meeting with the minister of Forestry, Lands and Wildlife on March 27, 1990, I was left with the impression that there might be public input to the IRP for northeastern Alberta, which was then only getting started. Because I have heard nothing more, I can only assume either that no IRP is being contemplated or that the policy of planning in secrecy is still in effect.

Forest Management Agreements

It is obvious to everyone except the minister and his senior advisers that conditions agreed to in secret negotiations between government and a proponent put severe limitations on any future remedial measures. Industry argues that to allow the public to comment on a draft of an FMA before it is signed would, in some mysterious way, jeopardize its competitive position. Because the FMA becomes a public document once it is signed, it is hard to see how publishing a draft could have a negative effect.

In a world free of government paranoia, the public would have input into IRPs and would be allowed to scrutinize draft FMAs to make sure that their terms did not contravene the planning decisions.

Forest Management Plans

The minister, in an uncharacteristic concession to democracy, now believes that the public should have input to Forest Management Plans (FMPs). Of course, that is a perfectly harmless place for public input because, in the final analysis, the FMA holder can ignore all suggestions put forward by the public. It is hardly a "level playing field," and it will not satisfy the public's desire for the meaningful input identified by Ms. Moen and others.

THE PROFESSION OF FORESTRY

I am sure that you have all heard variations on the old saw that "discipline X is too important to be left to the specialists" where X can be any discipline, such as politics or economics. I argue that the old saw applies with equal or greater force when X = forestry.

This is not a new or original thought. As far back as 1988, Fred McDougall, then deputy minister of FLAW said

> Yet, a lot of the decisions with respect to the boreal mixedwood forests are not going to be made by foresters. There is an important requirement here to involve wildlife management in a major way and to involve other elements in the resource management spectrum.

I suggest that if he were here today, he would have the same opinion about management of aspen, but the word has not made its way to Fred's successor or to the minister.

I submit that most of the concerns of the public arise from the simple but undeniable fact that decisions have been, and are being, made by foresters alone. No other "elements of the resource management spectrum" have a real say in decision making.

In this province, apparently, foresters are the people afflicted with tunnel vision who equate "forests" with "fiber" and who make no distinction between a forest and a plantation. In short, they seem to be unable to see the forest for the trees (hence the subtitle for this talk). They emphatically do not speak, in public at least, in support of forests as ecological systems that provide many benefits in addition to fiber.

This symposium is a case in point. If I counted them correctly, there are 24 foresters on the program and five others, four of whom are confining their remarks to wildlife. As nearly as I can tell from the titles of papers, there is not a single Registered Professional Forester (RPF) dealing with anything except consumptive use and regeneration of the trees. In everyday language, that is known as wood butchery.

Have Alberta foresters heard of Jerry Franklin and the so-called "new forestry"? Do they know about the "young turks" in the United States Forest Service who think Franklin's ideas are already obsolete? Do they care? Why is there no one on the program who is presenting these new ideas? Where is Stan Rowe? or Herb Hammond? or Everett Peterson? or Dean Baskerville from the University of New Brunswick? The attitude seems to be, "Don't

challenge me with new ideas, my mind's made up!"

According to Dancik, professional foresters "formed the Alberta Registered Professional Foresters Association (ARPFA), partly in response to *the need to protect the interests of the public in the management of the forest resources of Alberta* (my emphasis). In my view, they have done a lousy job of protecting my interests.

Is there not even one member of ARPFA who disagrees with the single-minded pursuit of fiber at the expense of all other forest uses and users? If there is, why does he or she not speak out in the interests of the public if that is really one of the aims of ARPFA? No conspiracy of silence is required in other professions. Medical doctors, who are not known for radical views, speak out on both sides of the abortion issue, for example. Consider also the vigorous debate in the wildlife management community over game ranching. Of course, that debate is largely fueled by academics. In the forestry camp, even academics, with the conspicuous exception of Bruce Dancik, seem to wear muzzles.

When I first came to this city, the Edmonton Journal used to have a slogan on its masthead, "Where all think alike, no one thinks very much." Does that apply to the professional foresters of Alberta? There is another saying—"If the shoe fits, wear it."

As a parting shot, I note that ARPFA has a code of ethics, which says, in part, that members should consider their prime responsibility to be "the maintenance of the integrity of the forest resource, the protection and enhancement of its productive capacity, and the perpetuation and improvement of its utility and value to society." The penalty for noncompliance is censure and possible loss of professional status. Well, I have tried to suggest that the "integrity of the forest resource" and its "value to society" has been, and is being, compromised in a multitude of ways with the active connivance and support of people who put RPF after their name and whose salaries are paid from the public purse. That really scares me.

If the fate of all our forests, not just aspen, is determined by secret deals negotiated by foresters, and if those foresters consistently break their own code of ethics, and if foresters maintain their conspiracy of silence when it comes to defense of the broader public interest, it is axiomatic that the public interest must continue to suffer.

Foresters, the ball is in your court.

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SESSION IV

SUSTAINABILITY AND INTENSIVE MANAGEMENT OF THE ASPEN RESOURCE

Moderator: A. Brennan
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HISTORY OF ASPEN SYMPOSIA IN WESTERN CANADA: COMMENTS OF THE SESSION MODERATOR

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Canada's forest industry has focused increasingly on the management and utilization of aspen in the past 15 years. The growing number of aspen workshops, seminars, and conventions suggests that this interest is intensifying. Edmonton hosted one of the first major poplar utilization symposia back in 1974. The one with which I was personally and heavily involved was the symposium Bill Young and I put together in Prince George, B.C., in 1978, entitled "Utilization of western Canadian hardwoods." Ontario sponsored a symposium in 1980 and 1982, both at Thunder Bay, dealing with boreal mixedwood. Whitecourt was the host town for a symposium in 1985 called "Utilization of hardwoods in northern Alberta." The Forest Industry Development Division of the Department of Forestry, Lands and Wildlife held workshops on aspen wood quality and aspen pulp, paper, and chemicals in 1987. In 1988, Edmonton held a very successful symposium, "Management and utilization of northern mixedwoods." I had the pleasure of being the keynote speaker at what was also a very successful convention at Fort St. John in the fall of 1989 on northern mixedwood. The attendance and quality of presentations at this aspen management symposium continues to confirm incredibly strong interest in this subject.

Brennan, J.A. 1991. History of aspen symposia in western Canada: Comments of the session moderator. *In* S. Navratil and P.B. Chapman, editors. Aspen management for the 21st century. Proceedings of a symposium held November 20-21, 1990, Edmonton, Alberta. For. Can., Northwest Reg., North. For. Cent. and Poplar Counc. Can., Edmonton, Alberta.

GENETIC IMPROVEMENT OF POPLAR IN WESTERN CANADA: ALTERNATIVES, OPPORTUNITIES, AND PITFALLS

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ABSTRACT

Some factors related to the establishment of genetic improvement programs for poplar in western interior Canada are reviewed. Opportunities with aspen, balsam poplar, and hybrid black poplar are compared. It is concluded that substantial genetic improvement is possible in a relatively short time with each of the several species groups adapted to the region. Initiation of programs should be preceded by a thorough, formal problem analysis that gives special attention to the degree and mode of artificial regeneration in the region.

INTRODUCTION

It now appears certain that Canada's aspen resource will soon come under the same utilization pressure as boreal conifers. This use and the attendant increase in silvicultural activity have already focused some attention on the opportunity for genetic improvement. Before investment in breeding programs is made, however, a thorough analysis of this opportunity is required. This is necessary because of the numerous approaches one might take in developing genetically improved material and because of the special nature of aspen silviculture. There are opportunities both for profitable research and development and for wasting money and human resources. The history of tree improvement (mostly unwritten) is littered with the carcasses of abandoned programs whose failures are founded upon combinations of poor planning, unreasonable expectations, inadequate financing, and bad management—or simply changing times and people. Although good planning cannot always avoid all these problems, it can reduce their probability. This presentation is neither the result of the required analysis or a literature review, though I will insert some key entrances to the literature. My comments will, however, draw your attention to some important considerations related to tree improvement programs. I will be concerned with aspen (*Populus tremuloides* Michx.) and balsam poplar (*P. balsamifera* L.) in the boreal forest region or *Populus* material that can be grown in these areas.

SHOULD THERE BE A GENETIC IMPROVEMENT PROGRAM?

The first question to be resolved through tree improvement analysis is whether to attempt breeding at all. This is a particularly important decision in aspen silviculture, where natural regeneration will be predominant because of root suckering. Analyses leading to choice of species and programs are thoroughly considered by Zobel and Talbert (1984). I examined the problem of species selection and decision making in hardwood breeding programs about 18 years ago (Farmer 1973). In brief, one needs to formally consider such things as value, silviculture, and genetic and physiological characters when determining the feasibility of breeding. Perhaps the key factor in the decision is the degree to which artificial regeneration will be used. Unless there are plans for large-scale artificial regeneration, through which improved material can be incorporated into production systems, tree breeding should receive low

Farmer, R.E. 1991. Genetic improvement of poplar in western Canada: Alternatives, opportunities, and pitfalls. *In* S. Navratil and P.B. Chapman, editors. Aspen management for the 21st century. Proceedings of a symposium held November 20-21, 1990, Edmonton, Alberta. For. Can., Northwest Reg., North. For. Cent. and Poplar Counc. Can., Edmonton, Alberta.

priority. And although availability of material with improved genetic potential can positively influence the feasibility of planting relative to natural regeneration, to date it has not usually been a deciding factor. The published reviews and analyses of aspen silviculture in western Canada (Navratil et al. 1989, 1991; Peterson and Peterson 1991) deal almost exclusively with natural regeneration, suggesting that artificial regeneration will play a minor role. This should be heavily weighed in an analysis.

Another closely related issue is rotation length, which I have been requested to address in relation to improved material. For several reasons, the genetic improvement of poplar in North America has been associated during the past 30 years with short-rotation (<15 years) silviculture. Although this may be a natural association in areas where productivity peaks at an early stand age and rates of growth warrant high cultural investment, I don't think that short rotation systems are necessarily appropriate in the boreal forest region (lat. 47°+). There is something about cutting down trees just when they are beginning to make wood that bothers me. Moreover, as Doucet (1989) has noted, there is some evidence that short aspen rotations (<10-15 years) lead to reduced yields in successive rotations. Other analysts (e.g., Perala 1979; Steill and Berry 1968) recommend a minimum rotation of about 15 years. I advocate aiming breeding efforts at normal rotations (40 years) and perhaps even giving some attention to developing material that has the genetic potential for better productivity during old age. (This is the sort of viewpoint one develops once you reach age 60.)

A second key element in a decision to establish a breeding program concerns the probability and cost of making substantial genetic gains in important characteristics such as growth. Although genetic data from the sort of studies that have been reported for other *Populus* species are almost nonexistent for aspen, there are numerous reports of phenotypic variation among putative natural clones. Together these studies suggest that there is wide genetic variation in most of the examined characters. Moreover, breeding procedures and propagation techniques have been developed. In short, there are excellent possibilities for genetic improvement. The purpose of this paper is to draw some conclusions about the relative merits of the several breeding alternatives.

Apart from the development of breeding programs designed to improve planting stock, it has been suggested that genetic information can be used to improve aspen within the context of natural regeneration systems. Because aspen and balsam poplar clones occur naturally, one might silviculturally eliminate poor clones and expand good ones. This possibility was recognized long ago by the University of Michigan group that first reported the existence of easily identifiable clones (Barnes 1966, 1969). Although the concept is attractive, its application requires 1) an intensity of silviculture that may not be realized in the boreal forest in the near future and 2) some silvicultural rather than genetic research. Therefore, I mostly note it in passing.

BREEDING ALTERNATIVES PRESENTED BY SPECIES GROUPS

Having generally concluded that if there is a need for genetically improved stock it can be produced, I would like to compare the relative merits of the several available breeding alternatives, keeping in mind the silvicultural context in which materials will be used.

Aspen

I believe that a well-conducted aspen breeding program can produce material with substantially improved genetic potential for growth and wood properties in a relatively short time (i.e., 15-20 years). Having said that, I must again note that with the exception of reports on a few isozyme studies (e.g., Cheliak and Dancik 1982) and one full-sibling progeny test (Einspahr et al. 1967) there are essentially no published genetic data on *Populus tremuloides* (Einspahr and Winton 1977). There have been no range-wide provenance tests or even provenance tests covering major portions of the tree's range. There are, to the best of my knowledge, no clonal or progeny tests underway, though I understand some are being designed. As I briefly noted above, practically all of our insight into genetic variation in aspen has come from studies of phenotypic variation among purgative natural clones. These have been valuable, but if

serious breeding is to be done, we will have to generate a better foundation of genetic information. I therefore hesitate to make estimates of genetic gain for most characters. We do have data from a variety of studies, however, that suggest that wood specific gravity can be easily increased from the present average of about 0.36-0.38 to over 0.40 (Farmer, in press).

On the positive side, methods of crossing aspen have long been known and are easy to use (Einspahr and Winton 1977). Full-sibling progenies from many families can thus be readily produced. Successful vegetative propagation (via softwood cuttings of juvenile material) has been with us since mist propagation was introduced in the 1950s (Farmer 1963). In short, there are no technical barriers to breeding, and there are several useful program designs. Choice of one should stem from a thorough problem analysis and will depend upon organizational capabilities and objectives.

The most conceptually simple aspen program might consist of selecting phenotypically superior clones followed by formal clonal tests after vegetation propagation. This route hinges on the operational use of clones and associated large-scale vegetative propagation. This propagation is feasible but more costly and risky than black poplar propagation. Tissue culture may ultimately reduce this cost; however, in my estimation, program design should drive tissue culture development, not the reverse.

Clone selection and testing is most logically an initial phase of a broader breeding program because it soon reaches a genetic dead end. I have other reservations because it will probably result in a tendency to operationally use a limited number of clones, even more than in black poplars. This isn't an inherent result of such a program, but it is likely.

A much more fruitful approach would be to use selected clones as parents in a program of recurrent selection. The central feature would be a series of full-sibling progeny tests from which one might select parental combinations with high specific combining ability, i.e., individual crosses that produce exceptionally good progeny. Seed orchards or breeding houses incorporating these parents would produce seedlings for planting rather than cuttings.

Such a program might also incorporate production of the hybrid of *P. tremuloides* and *P. tremula* L., which has been used in Scandinavia. Work at the Institute of Paper Chemistry at Appleton, Wisconsin (Einspahr 1984), has produced hybrids of these two species that have shown promise in the Lake States and as far north as 49° latitude in northwestern Ontario. A program for western Canada, however, should involve local *P. tremuloides* parents and should not simply consist of testing hybrid material developed in other regions. Moreover, a hybridization program should use the best material available, not just convenient parents.

Whatever the breeding approach taken with aspen, some concurrent assessment must be made of genetic variation patterns, especially for growth and its closely related characters such as photoperiodic response. For example, given what we know about other *Populus* species, it is very likely that simply moving material a few hundred kilometres north of its origin will result in improved juvenile height growth. Provenance tests may be considered old-fashioned by some folks, but when properly designed to provide an overall assessment of variation patterns within and among populations, they still provide the best information and material upon which to base a breeding program.

Whether seedlings or rooted cuttings, the products of an aspen program will probably be easier to incorporate into the forest than most black poplar material. Experience at the Institute of Paper Chemistry (Benson 1972) and elsewhere indicates, however, that a substantial investment in site preparation and weed control is still necessary. The most distinct incorporation advantage with aspen is that relatively low-cost natural regeneration via root suckers will be used in subsequent rotations.

Balsam Poplar

Balsam poplar makes up as much as one-third of the basal area in western "aspen" stands (Navratil et al. 1989), and there is every reason to believe that it will soon be used right along with aspen. This is good news from the standpoint of tree improvement, for in some respects balsam poplar is an easier species to breed than aspen. Is there a more perfect tree than one which

regenerates by seed, stump sprouts, root suckers, and even buried branches? Before investment in genetic improvement is made, however, one must determine to what degree balsam poplar will be encouraged relative to aspen. At the moment there are few data indicating how, when, and where balsam poplar is to be grown. An examination of the dynamics of aspen-balsam poplar mixes under various site conditions may be appropriate before a silvicultural policy is set.

Should it be desirable to plant balsam poplar, there are, I believe, very good opportunities for genetic improvement of yield. First, like aspen, balsam poplar has characteristics that facilitate breeding. And the fact that balsam poplar can be easily propagated by stem cuttings gives it an advantage over aspen. Secondly, there are a few existing long-term genetic studies that have already provided encouraging data on variation and inheritance. The USDA Forest Service's Genetics Institute at Rhinelander, Wisconsin, will soon publish data on inheritance of juvenile growth characteristics for the population in northern Wisconsin and the upper peninsula of Michigan. Our provenance-clonal test at Lakehead University is not over 5 years old and is ready for an initial report. Due mostly to an almost classical provenance difference in photoperiodic response, northern Wisconsin material growing at Thunder Bay outperforms the local population by about 15% in terms of height increment. We have already published data on inheritance of a variety of other characteristics, some of which don't exhibit much provenance variation but do vary substantially among clones within populations (Farmer, Chaliak et al. 1988; Farmer, Garlick et al. 1989; Schnekenburger and Farmer 1989). Material in these studies represents only a fraction of balsam poplar's range, and data from the western area will be required for a breeding program there. There is, however, every indication that rapid improvement is possible.

The general design of a balsam poplar breeding program will probably take the form of field selection, clonal testing, and full-sibling progeny tests ultimately leading to a system of recurrent selection, as in other poplars. Because of easy vegetative propagation, clonal testing will be simpler than in aspen, and there will be the usual danger of slipping into the production of "a few fine clones." There is also some potential for using improved balsam poplar as parents in interspecific hybridization.

Hybrid Black Poplars

Perhaps no words in forestry lingo have been more misused and misunderstood than "hybrid poplar." As well noted in Zobel and Talbert's (1984) forest genetics text, the term hybrid has been used to refer to everything from the products of intraspecific crosses of closely related material to the progeny of interspecific crosses. They further correctly note that there is nothing genetically superior about hybrids, though there are instances of tree hybrids exhibiting characteristics superior to either parent. I believe that when we use the term hybrid poplar we should refer to progeny of a certain interspecific cross that is noted along with the term (e.g., hybrid of *P. deltoides* x *P. balsamifera*). I further believe that we should rid ourselves of both the loose use of the general term and the mystique surrounding it.

Having said that, I believe there may be good opportunities for improving poplar yield in western Canada through the use of hybrids of *P. deltoides* Bartr., *P. balsamifera*, and *P. trichocarpa* Torr. and Gray. This improvement will, of course, hinge upon 1) substantial planting programs, 2) intensive culture, and 3) proper site selection. The one thing we know best is that growth of black poplars will fail without a level of establishment culture that is foreign to many foresters. There are many situations in which such culture just doesn't make economic sense in light of product value and rotation length.

The best existing genetic information on hybrids comes from the University of Washington's breeding program with the *P. deltoides* x *P. trichocarpa* hybrid (Heilman and Stettler 1985; Rogers et al. 1989). This hybrid, which involves *P. deltoides* from the lower Mississippi valley (lat. 33°N) and local Washington *P. trichocarpa*, is distinctly more productive than either parent when grown in western Washington. Moreover, it has been grown for several years inland at a higher latitude in British Columbia with impunity (Carlson 1990). It is especially interesting that a hybrid involving one parent from lat. 33°N appears to be photoperiodically adapted to 50°N.

There is a good possibility that *P. deltoides* x *P. trichocarpa* hybrids produced by the Washington program may be useful in a more northern interior area, and they should be tested there. It may also be useful to produce and test this hybrid using parents from regions closer to the point of use.

Putative natural hybrids of *P. deltoides* and *P. balsamifera* (i.e., *P.* x *Jackii*) are abundant in collections of hybrid poplar being tested at several locations in the boreal forest region. Some of them show promise, though there are few good comparisons of them with their parents. Some *P. deltoides* x *P. balsamifera* hybrids have also been produced in breeding programs. I believe hybrids of good *P. deltoides* and *P. balsamifera* genotypes adapted to the west may be useful.

The third potential hybrid is that of *P. balsamifera* x *P. trichocarpa*. The ranges of these two species have a common border along which there is probably a good bit of natural hybridization. In fact, some authorities consider *P. trichocarpa* a subspecies of *P. balsamifera* (Scoggan 1978). To the best of my knowledge there has been no major experimental work aimed at producing hybrids of these species. In addition to the hybrid vigor (or heterosis) sometimes exhibited by progeny of wide crosses, some hybrids of *P. balsamifera* might exhibit root suckering, a very desirable trait. In fact, root suckering would revolutionize silvicultural systems for black poplar by eliminating the need to replant after harvest. The genetics of root suckering is essentially unknown, though phenotypic variation in suckering capability of aspen has been noted.

There are collections of various "hybrid poplars" at several research institutions in eastern Canada and the United States. These have variable pedigrees and have been used with various degrees of success. Most are more suitable for latitudes south of northwestern Canada, and many are plagued with insect and disease problems. Should production of black poplar hybrids become a breeding goal in western Canada, some of this material should be incorporated in long-term tests. However, I believe it would be a mistake to make these hybrids a centerpiece of an improvement program.

CONCLUSIONS

In my invitation to speak at this symposium I was requested to compare aspen versus hybrid poplar in short rotations and tree improvement. I suppose I have rejected short rotations in the boreal forest, though I suppose if someone wants to worry about harvesting and regenerating little trees every 10 years rather than big trees every 50 years that's their business. I suggest that they check with a good economist first. I have also suggested discarding the term "hybrid poplar" as a single group of materials that might be contrasted with aspen. Several sorts of material may have a place in western poplar production systems. Before beginning their development one must determine whether there will be enough artificial regeneration in the region to warrant any genetic improvement program. If the answer is yes, then the nature of the program in terms of species will depend upon the kind of sites to be planted and the silvicultural systems that will be used on them. A review of existing information suggests to me that aspen (and perhaps its hybrid with *P. tremula*) should receive priority because of its greater site adaptability and its root suckering capability. Despite my enthusiasm for balsam poplar as the tree breeder's perfect tree, I see the species mostly as a hybrid parent unless it can be shown that it should be favored over aspen. Should the region contain enough flood plain sites (unsuitable for aspen) to warrant planting balsam poplar, then of course breeding might be warranted. Serious consideration of hybrids of black poplar will require a commitment to intensive culture on good sites.

Whatever the mix of sites, species, and resulting silvicultural systems, a decision to establish a poplar improvement program should be prefaced by a formal problem analysis that thoroughly considers the demand for improved stock and how it will be used. Products of an analysis will be a species priority and a breeding strategy for each. Plans resulting from such an analysis should be translated into a program supported by a long-term financial commitment at the outset. Without such a commitment it is probably better not to begin a program so that money will not be wasted in small ineffectual increments. Given the substantial industrial interest in the resource, support and

participation by industry should be a key element in a program.

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SHOULD WE THIN YOUNG ASPEN STANDS?

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ABSTRACT

The large aspen (*Populus tremuloides* Michx.) resource in western Canada is rapidly being committed to pulp and flakeboard manufacture. Yet shortfall in annual allowable cut (AAC) is unlikely in the next 20 years. Precommercial thinning, or spacing, can accelerate tree growth and reduce the time needed to grow usable size material; however, this will not increase stand production and AAC, especially with the close utilization of the above products. This paper discusses biological implications and provides financial analysis of several spacing cost-benefit scenarios following the treatment of dense, juvenile aspen stands on productive sites. It touches on the feasibility of merchantable thinning in pole-size stands.

INTRODUCTION

Thinning dense, young stands can shorten the time needed to produce usable (merchantable) wood, but at a substantial extra cost that easily exceeds the benefits. Whether or not to thin depends on the management objective and the value of the products or benefits in that area.

The principal timber management objective for aspen stands in western Canada—by which we mean Manitoba, Saskatchewan, Alberta, and northeastern British Columbia—is the production of low-cost wood fiber for pulp and flakeboard manufacture. Given a stable market price and manufacturing costs for these products, remote markets and associated high transport costs mean that an economically viable operation is guaranteed only by low wood costs. Other objectives and uses—recreation; aesthetics; wildlife habitat improvement (e.g., providing winter food for ruffed grouse by favoring male aspen clones)—are important but are not directly considered in this paper.

When today's researchers talk about thinning, they usually present some fairly complex density management diagrams for the species concerned (Fig. 1). These diagrams show the recommended number of trees left in a stand to attain certain average tree size statistics, which for precommercial thinning may be best expressed in terms of height. The objective is to open the stand to achieve near-optimum growth for a period of time until the next thinning entry, and so on. Although this approach may be suitable for fast-growing, high-value species like Douglas-fir on the coast, it is clearly unfeasible for low-value timber such as trembling aspen.

The current explosion in aspen use in this region means that large areas are harvested and are then regenerating to dense, young, sucker stands. Forest managers are therefore thinking and asking questions about thinning such stands. We will try to answer these questions, taking into consideration aspen stand growth and development within current timber management objectives and within the current financial environment. This approach ensures both the biological and financial viability of such treatments.

The topic of this talk is "Should we thin young aspen stands?" We could give a firm "no" answer without hesitation. As this would likely be much too short for a talk and also unconvincing, we will present supporting information.

Bella, I.E.; Yang, R.C. 1991. Should we thin young aspen stands? *In* S. Navratil and P.B. Chapman, editors. Aspen management for the 21st century. Proceedings of a symposium held November 20-21, 1990, Edmonton, Alberta. For. Can., Northwest Reg., North. For. Cent. and Poplar Counc. Can., Edmonton, Alberta.

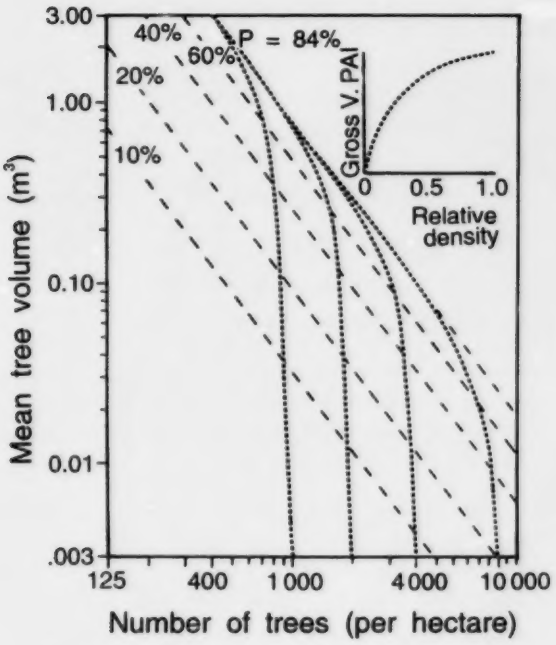

Figure 1. Stand density management diagram for lodgepole pine (from Flewelling and Drew 1985).

SOME BASIC ASSUMPTIONS AND CONSIDERATIONS

1. The principal demand for aspen wood fiber will continue to come from flakeboard (mainly oriented strand board [OSB]) and pulp manufacture. These uses imply close utilization, preference for size uniformity, and no premium on large logs. None of these conditions indicates a need for thinning.
2. Although the age-class distribution of current aspen stands is far from regular, available uncommitted aspen timber resources in the region make any shortfall in AAC unlikely in the next 20-year planning horizon.
3. Although aspen sucker regeneration can reach very high densities, especially under ideal conditions (over 100 000 per hectare; Bella 1986), those densities rapidly decline due to the nature of sucker regeneration (Navratil and Bella 1988) and the extreme intolerance of the species. This again alleviates the need for thinning.

   Although an aspen root segment on a cutover may produce one-half-dozen suckers, only the most vigorous will survive beyond the first two to three years. Mortality is very rapid at high densities at this time; stem numbers drop to below 30 000 by age 6, and to below 15 000 by age 16. This occurs regardless of the season of logging and the amount of slash on the ground (Bella 1986). Although this information is from cutovers in east-central Saskatchewan that were logged in the mid-1960s, they should generally apply to aspen stands in the boreal forests of western Canada under similar logging conditions. This means that young, dense aspen sucker stands will naturally thin themselves and maintain vigorous growth and good production.
4. Thinning treatments in aspen stands—and here we mean precommercial thinning or spacing—that favors the biggest, most vigorous individuals accelerates tree growth, as production is distributed among fewer trees (Bickerstaff 1946; Schlaegel 1972; Perala 1978). Yet total production of the stand is not improved, but reduced (Bickerstaff 1946; Jarvis 1968; Schlaegel 1972), because the area is usually understocked at least for a few years immediately after thinning (Fig. 2). As only stems above a certain size are usable, however, trees in thinned stands reach this size well before those in unthinned stands. This then can mean a reduction in rotation age. As decay losses accelerate with increasing age, reduced rotation length is an advantage.

FINANCIAL IMPLICATIONS

At present, the Alberta Forest Service uses a 60- to 80-year rotation for aspen in AAC calculations, depending mainly on site class and productivity. With precommercial thinning, the 60-year rotation on good sites may be reduced by 10 years, to age 50. We examined the financial feasibility of such a treatment in a hypothetical stand where the rotation is reduced by 10 years, but harvest yield remained the same—a very generous assumption indeed. Our main findings were as follows (see Table 1):

- only at an unrealistically low treatment cost ($100 per hectare) and a very high wood

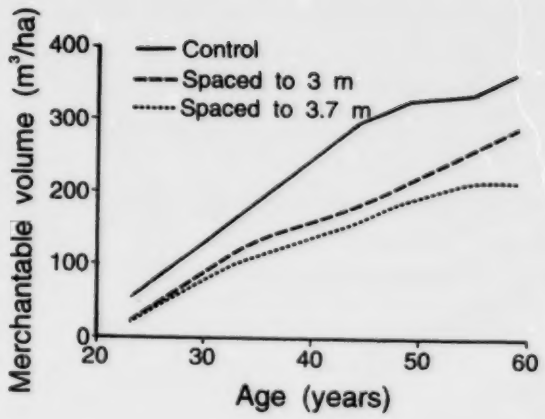

Figure 2. Merchantable stem volume production (stump height 15 cm; top diameter inside bark 8 cm) of aspen thinned at age 23 to three density levels, Riding Mountains, Manitoba.

market price ($10 m^3/ha) is thinning dense 5-year-old aspen financially feasible;

- delaying treatment to age 10 only slightly improves returns;
- no treatment is even remotely viable at realistic thinning costs between $300 to $500 per hectare, even at a wood market price of $15/m^3.

A scenario often used to justify the thinning of aspen is when a gap in age-class distribution causes a shortfall in available AAC. Then the financial analysis has to allow for this, possibly through appropriate wood market price adjustment.

CONSIDERATIONS IN FAVOR OF THINNING

1. Thinning provides an opportunity for upgrading stand quality in terms of growth performance and insect and disease resistance (Steneker 1976). Tree growth characteristics and associated stem quality, as well as insect and disease resistance, generally have a strong genetic component. They thus provide an opportunity to improve stand quality through judicious tending practices based on readily observable clonal characteristics. Undesirable clones with poor growth habits or susceptibility to disease can be identified and removed. This "sanitary thinning" is feasible in aspen stands where trees of different clones are intermixed rather than clumped (Navratil 1987).
2. There is opportunity for enhancing aesthetic qualities.
3. Wildlife habitat, both for mammals and birds, may be improved.
4. Aspen is sensitive to water stress (Sucoft 1982), and it may withstand drought from climatic warming in thinned stands with reduced water demand.

WHAT ABOUT MERCHANTABLE THINNING?

Some past studies showed that merchantable thinning could be biologically justified on good sites (Hubbard 1972) at least up to 40 to 45 years of age (Weingartner and Doucet 1990), as the remaining trees may take advantage and respond to the extra available living space. This may sound attractive and reasonable, but several potential problems may arise: 1) the operation and the wood produced is too expensive; 2) virtually any kind of logging—especially mechanized—will cause some stem-bark and root damage that provides entry points for fungi and results in rapid stemwood decay and volume losses (because of thin bark and the lack of strong protective response); 3) increased incidence of Hypoxylon canker (which can kill trees in a relatively short time), sun-scald, and possibly wind and snow damage; 4) canopy opening can lead to the establishment of a shrub and herb layer, which may hinder aspen regeneration. Points 3 and 4 may apply to all thinned, relatively open stands.

CONCLUSIONS

1. Although thinning young, dense aspen stands accelerates tree growth and enhances the production of usable material and allows earlier harvest, such treatment is generally financially unviable and biologically risky.
2. If aspen thinning is undertaken, it should be done as soon as dominance is expressed and readily observed. Trees should be between

Table 1. Financial returns at age 50 after thinning dense 5- and 10-year-old, highly productive (SI = 24 m) aspen stands to 3000 trees/ha using four cost scenarios. Final harvest yield 350 m^3/ha (5000 ft^3/ac.; MAI 100 ft^3), gain for the 10 years 58.3 m^3.

Treatment cost ($/ha)	Age at treatment	Internal rate of return (%) (market value of wood in $/$m^3$)		
		5	10	15
100	5	2.40	4.00	4.94
	10	2.71	4.51	5.57
200	5	0.84	2.41	3.33
	10	0.94	2.71	3.75
300	5	(-0.07)	1.49	2.40
	10	(-0.80)	1.67	2.71
500	5	(-4.12)	(-0.34)	1.25
	10	(-1.34)	0.38	1.41

4 to 6 metres in height and 5 to 10 years of age. This would leave between 1500 to 3000 of the best quality and largest trees per hectare in a sanitation mode based on clonal characteristics.

3. Even under the above conditions, thinning should only be done on good growing sites that have a low risk of Hypoxylon infection.

It is no surprise that Don Perala, Minnesota's Mr. Aspen, gave only a qualified yes to thinning aspen in the Lake States, where wood demand and use are high and supply shortages are anticipated by 2010. Yet he predicts less than 5000 ha of aspen thinned in Minnesota in the next 20 years.

All this would also suggest that rather than getting side tracked on aspen thinning, we need to concentrate on some really critical sivicultural problems that require immediate attention and action, for example, what to do with decadent overmature stands and how to ensure adaquate suckering for full stocking, and rapid growth through the selection of a suitable method and time (season) of logging in a site-soil and climate-weather framework.

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ASPEN DEVELOPMENT AND PRIVATE-LAND FORESTRY

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ABSTRACT

Every woodlot in Saskatchewan has some aspen trees. There are 15 000 woodlots in our province, the majority of which are completely unmanaged today. As more people become aware of the uses for aspen, both traditional uses and new uses created by technological advances, we will look to our forgotten bluffs with a renewed interest. Aspen is "user friendly"—easy to regenerate and quick to grow. It will be the tree that connects many of our 15 000 woodlot owners with the practice of woodlot management.

Today I want to discuss the implications for private-land forestry in light of the new and growing industrial demand for aspen across the prairie provinces, in particular in my home province of Saskatchewan.

Saskatchewan has about 1.5 million acres of existing private forest land owned by about 15 000 individuals. Approximately 90% of this land is now growing aspen and black poplar. We have two and soon will have three industrial users of aspen. The Farm Woodlot Association is confident that we can supply these and additional users from our existing land base. We have reason to believe that our current land base can produce over $100 million annually in wood fiber, which will be a welcome shot in the arm for our rural economy.

In 1990, however, we estimate that our private woodlands produced a mere $3 million. Why? The lack of strategically located industries is partly to blame, but I think the major factor inhibiting the development of private-land forestry is wood prices. The prices currently paid by industry for private wood reflect the cost of harvesting, period. In the marketplace, where supply and demand set the scene, industries have access to more aspen than they need on the publicly owned forest land that they lease. Private wood is purchased only out of convenience.

How can this be changed? Well, more industries will undoubtedly increase competition, which can eventually increase prices. However, this will not happen immediately. In Saskatchewan we woodlot owners are working towards establishing a marketing system in which the landowner has a bit more say. We look to Quebec and New Brunswick where woodlot owner organizations have gained significant benefits for their members. With assistance from provincial governments, these two groups have developed orderly marketing. Their governments have enacted primary source legislation laws that direct industries to make purchase contracts with woodlot owner groups before getting access to public forests. The result in both provinces is that the prices paid to woodlot owners for this wood are more than double those paid on the prairies.

For many of you, industrial and government foresters and managers, the idea of including private-land fiber in the supply equation is entirely new. Do not jump to conclusions about some of the things I have just mentioned without thinking about them in more detail. The forest industry in Canada, and especially on the prairies, has been based on inexpensive wood from Crown forests. This fiber supply situation is unique in the world. It results in a virtual monopoly of demand. In most areas of the world forest industries and woodlot owners work together. We can look to these situations to get ideas. There will be many challenges but I'm sure that over time we can overcome some of them. Do not try and avoid us. Woodlot owners are not going away.

Shiell, H. 1991. Aspen development and private-land forestry. *In* S. Navratil and P.B. Chapman, editors. Aspen management for the 21st century. Proceedings of a symposium held November 20-21, 1990, Edmonton, Alberta. For. Can., Northwest Reg., North. For. Cent. and Poplar Counc. Can., Edmonton, Alberta.

In Saskatchewan, our government has a golden opportunity to diversify the economy and enhance the sustainability of our forest resources. With legislation in place the development of our vast aspen resource can truly be shared by a wide cross section of Saskatchewan people.

And while management of aspen is the obvious hook to attract woodland owners to woodlot management, the diversification into softwood and other hardwoods is an obvious extension of this development.

Aspen development may therefore be the key to the maintenance, renewal, and expansion of our private-land forests, forests that exist for the wide variety of important reasons we have been hearing about at this conference.

ASPEN IN A CHANGING CLIMATE

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ABSTRACT

In western Canada, aspen attains its best growth potential in the boreal zone under the present climatic conditions. The anticipated climate change within the next century, caused by anthropogenic actions, would result in a warmer climate and precipitation patterns similar to the present. Comparable conditions existed in western Canada during the mid-Holocene warm-dry period (about 6000 years ago), when grasslands and aspen parklands occurred far north of their present extent. The anticipated climate change would cause increased drought conditions in the south and a longer growing season in the north. Under such conditions aspen is expected to respond with generally reduced growth rates, higher mortality, and higher incidences of insect and disease infestations in the south. In the mid-range, aspen would benefit from the extended growing period with increased productivity. In the north, existing aspen stands would become more aggressive in expanding their range.

INTRODUCTION

In recent years, predictions of impending climate change have introduced a new dimension to the management of our forest resources. More than ever, forest managers must consider not only the direct effect of their management interventions, but must also consider the "natural" evolution of the forest ecosystems they attempt to manage, if they are to avoid the future shock that some have suggested will occur (Kimmins 1985). Although all renewable resource sectors will be significantly affected if the climate changes projected under the enhanced greenhouse warming take place, the forest resource sector, by virtue of the longevity of the species involved, has the opportunity to adapt or the potential to be adversely affected. This is because the predicted change will be so rapid that species migration and adaptation may be unable to keep pace. There is a consequent potential for major changes to vast areas of present forests and the possible loss of species (IPPC 1990).

Changes in the socioeconomic forces in a changing climate will also contribute to these ecosystem changes. Public interest increasingly forces forest managers to recognize multiple nontimber values of the forest as well as the traditional economic ones. Environmentally sustainable economic development that would not only prevent the degradation of the environment, but to some measure also enhance it for various multiple uses, is now recognized as an attainable goal (Maini 1990). This concept enters a different dimension, however, when the development has to be sustainable not only under the present environmental conditions, but also under changing climatic conditions.

This paper is an assessment of how western Canada's aspen resource might be affected by the projected climate changes. It is not our purpose to predict or explain what the future climate will be. We instead take the possible scenarios, as provided by the experts in atmospheric sciences, and try to evaluate, on the basis of current understanding, what the impact of these potential climate changes will be on the aspen resource.

CLIMATE CHANGE

The widely publicized concern for global warming arises primarily because of the observed increase in radiatively opaque gases (carbon dioxide, methane, etc.) in the earth's

Zoltai, S.C.; Singh, T.; Apps, M.J. 1991. Aspen in a changing climate. *In* S. Navratil and P.B. Chapman, editors. Aspen management for the 21st century. Proceedings of a symposium held November 20-21, 1990, Edmonton, Alberta. For. Can., Northwest Reg., North. For. Cent. and Poplar Counc. Can., Edmonton, Alberta.

atmosphere, resulting in an enhanced "greenhouse" warming. These changes are clearly linked with man's use of fossil fuels and to a lesser extent (20%) with changes in land use, which affect the carbon dynamics role of the vegetation.

Although the changes in the atmosphere are readily documented, the effect of these changes on the climate is less easily substantiated and is an active area of research fraught with uncertainty. Not only is the magnitude and rate of climate change based largely on theory, the manifestation of these changes (extreme events vs. averages) is speculative at this time. Although there remains a small group of scientists who dispute the results of a number of global warming projections as a result of the enhanced greenhouse effect, the world's scientific community generally agrees that there will be a significant, unavoidable climate warming. The Intergovernmental Panel on Climate Change reports reflect this consensus.

Table 1 from Environment Canada (1990) shows a comparison of the results from six independent global circulation models (GCMs) for projected global mean temperature and precipitation changes. The projections are for a period after climatic equilibrium has been reached in an atmosphere with an effectively doubled CO_2 loading. Normally referred to as the 2 × CO_2 scenario, this atmospheric loading is expected to be passed sometime towards the middle of the next century. The table also shows that four of the six models, including the Canadian Climate Centre's (CCC) 1990 model, indicate expected increased summer dryness for mid-continental North America.

A recent paper by Kellogg and Zhao (1988) compares five of the current GCM projections in some detail and provides comparisons of their North American projections in the form of maps. The Canadian GCM shows a qualitatively similar pattern. What is particularly striking is that in nearly all the projections the "bull's-eye" of change is focused on the mid-continent. The zones of largest temperature changes, which encompass most of the current aspen resource, are considerably higher than the global averages in Table 1. The CCC GCM, for example, shows temperature changes in the order of +4°C to +6°C for the region.

The 2 × CO_2 projections shown in Table 1 indicate the direction and approximate magnitude of the expected changes in a greenhouse-enhanced world. They do not, however, indicate the dynamics of the change. Some unusual weather patterns associated with the change may have severe consequences on the aspen resource (increased drought frequency, violent storms, deep wet snow, late spring frost, etc.), but such manifestations of the climate change are not readily predictable.

The point is that future climate projections currently indicate significant changes in primary factors (temperature and moisture) affecting forest processes. If these projections prove true, the forests being planted now will "mature and decline in a climate to which they are increasingly poorly adapted" (IPPC 1990). While we may be concerned about the lack of spatial and temporal precision in projections of the climate variables and be even more critical of their uncertain accuracy, we can use the current GCM results to explore the sensitivity of the forest resources to the possible changes that may occur. Using this approach, in this paper we explore the effect on the aspen resource if the climate were to shift towards the equilibrium 2 × CO_2 projections over the next century.

ECOLOGICAL BASIS FOR IMPACT ANALYSIS

There are several approaches to analyze the possible effects of a changing climate on aspen ecosystems. One approach is to compare the forests of an area to a region that has the anticipated climate according to the climatic change scenario. This would give an indication of the expected forests if a vegetative-ecosystem equilibrium could be reached under the changed climate. As this is not likely to happen, at best this approach gives an indication of the direction of vegetation change from the present to the anticipated climatic conditions at a certain time in the future.

Examination of vegetation dynamics on topographically induced local climate can give useful information. Slopes of southerly exposure are usually warmer and drier than the rest of the area, even though they share the same regional climatic regime. Conditions on such slopes may

Table 1. Experiment results from 2 × CO_2 and 1 × CO_2 global circulation models[a]

Model	Temperature change (°C)	Precipitation change (%)	Summer dryness
GFDL (1989)	4.0	8.7	yes
CISS (1984)	4.2	11.0	no
NCAR (1984)	4.0	7.1	no
UKMO (1987+)	1.9-5.2	4-15	yes
OSU (1987)	2.8	7.8	yes
CCC (1990)	3.5	3.8	yes

[a]Environment Canada 1990.

resemble the expected changed regional climate, with vegetation that is adapted to these conditions.

To evaluate the pace and magnitude of vegetational changes in specific regions, the climate-related characteristics of the forest ecosystems are examined. The effects of extreme climatic events that have occurred in the past, and may be expected in the future, can be used to indicate possible ecosystem responses. Documented effects of prolonged or severe droughts on aspen ecosystems can give indications of the expected response to increased droughty conditions. The distribution of aspen forests during a warmer and drier period up to 6000 years ago can give indications of ecosystem response to a different climatic regime. The results of such analyses have to be used with caution, as we do not know to what extent the expected climate change will approximate the past climates.

In addition to the uncertainties of the predicted climate change, the impact of the changing climate on the vegetation is also theoretical and unproven, as the anticipated climate change is unprecedented in its scale and rate. We have no clear previous experience on which to base our evaluation. The following account is therefore largely based on inferences derived from some knowledge of relevant environment-vegetation relationships.

PRESENT ASPEN PRODUCTIVITY

Biomass productivity of aspen stands varies with physiographic-edaphic conditions, stand density, genetic differences between stands, and their clonal structure. Regional productivity differences are notable and can be related to broad climatic differences, whether expressed on a forest region basis (Fig. 1) or as ecoclimatic regions (Ecoregions Working Group 1989). Thus, grove-type stands of the aspen-grassland ecotone have different productivity than the main boreal forest in west-central Canada.

Maini (1968) reported a strong effect of latitudinal change in the dominant height of mature aspen in Saskatchewan (Fig. 2). Measurements were made along a 1200-km north-south transect through the grassland, grassland-forest transition (ecotone), boreal forest, and into the edge of the forest-tundra transition. Aspen trees attained maximum height in the main boreal forest but were of considerably shorter heights northwards near the forest-tundra ecotone and southwards in the forest-grassland ecotone and in the grasslands.

Similar trends were detected in the total biomass production of aspen (Johnstone and Peterson 1980) when stands from the grassland-forest transition, the main boreal zone, and montane regions were examined. The montane stands were all from high elevations (>1370 m ASL), with climates similar to a more northern forest-grassland ecotone location. Tree

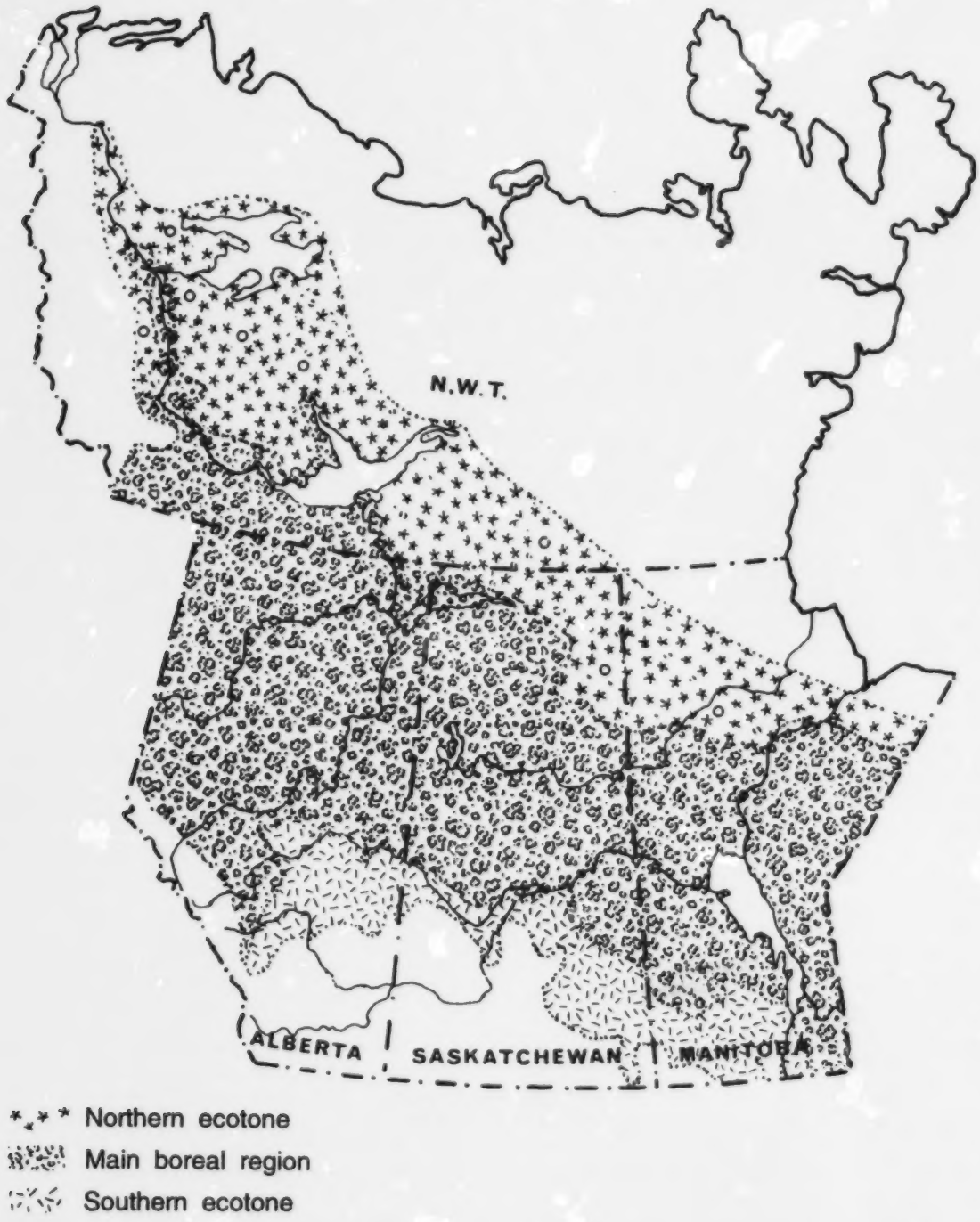

Figure 1. Main forest zones of west-central Canada (Rowe 1972).

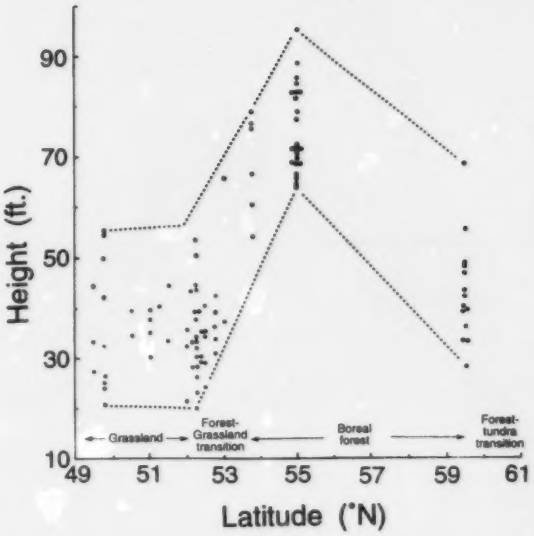

Figure 2. Height growth of mature aspen stands along a 1200-km north-south transect in Saskatchewan (Maini 1968).

component biomass from stands of comparable age were always greater in the main boreal zone than in either the montane or aspen-grassland ecotone (Fig. 3). Other productivity indicators, including height, diameter at breast height, crown dimensions, and leaf areas showed similar highly significant ($p < 0.01$) differences (Fig. 4).

These data indicate that aspen growth and productivity is sensitive to a climate gradient as reflected in regional latitudinal differences. Optimum conditions for aspen growth exist within the main boreal zone. Less suitable conditions exist near the southern and northern ecotones, apparently in response to climate-related environmental stresses. Should the projected climate changes occur, the optimum conditions for aspen growth will shift accordingly. In the southern (grassland-forest) ecotonal areas, aspen will be subjected to increasing stress and will be adversely affected, while in the northern (forest-tundra) ecotone, the direct climatic stresses should be reduced.

PROJECTED SOUTHERN ECOTONE

Projected climate change scenarios for the southern ecotone indicate warmer temperatures, especially during the winter. This would result in a higher number of growing degree days and a longer growing season. Precipitation predictions, although very uncertain, appear to be marginally higher than at present; however, the higher temperatures would result in increased evapotranspiration and thereby result in a reduction of ecologically effective moisture.

These conditions would favor the expansion of the grasslands at the expense of aspen. If conditions were stabilized at the $2 \times CO_2$ scenario, the likely response would be for the arid grasslands to advance north of Edmonton and Prince Albert and for the aspen parkland to extend north of Churchill River in Saskatchewan (Zoltai 1988). This would approximate the position of the boreal forest boundary about 6500 years ago, as determined from tree pollen (Ritchie 1976) and peat formation (Zoltai and Vitt 1990).

The distribution of aspen in the southern ecotone appears to be controlled by recurring severe droughts. The drought of 1961 resulted in up to 100% mortality in aspen groves in the southern Saskatchewan and Manitoba portions of the ecotone. Some trees were killed outright, while others succumbed to the weakly parasitic fungus, *Cytospora chrysosperma* that attacked the weakened trees in the years following the drought (Department of Forestry 1961, 1962, 1963).

The drier climate would result in more forest fires that would burn larger areas than at present. This would further facilitate the spreading of grasslands into formerly treed areas.

The rate of vegetation change due to the changing conditions will depend on disturbance regimes (Overpeck et al. 1990), which in turn depend on the weather patterns in the changing climate. If severe droughts occur at frequent intervals, aspen ecosystems could be destroyed rapidly by the drought and attendant insect and disease attacks. This would cause the most immediate changes in the southern fringe of the ecotone. In the rest of the area, some aspen

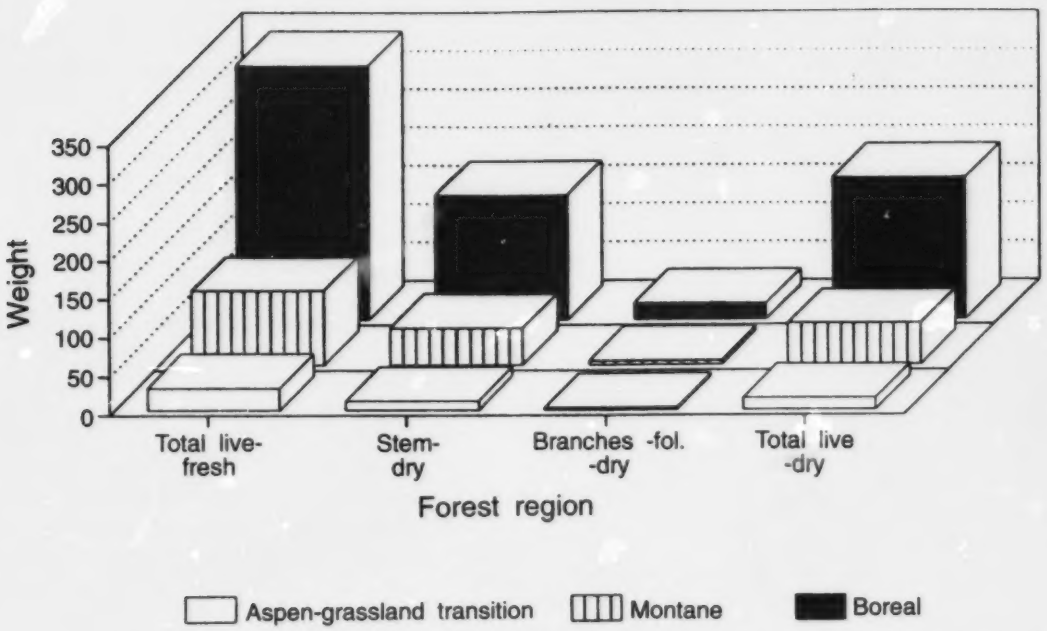

Figure 3. Aboveground biomass of aspen in different forest regions in Alberta (recalculated from Johnstone and Peterson 1980).

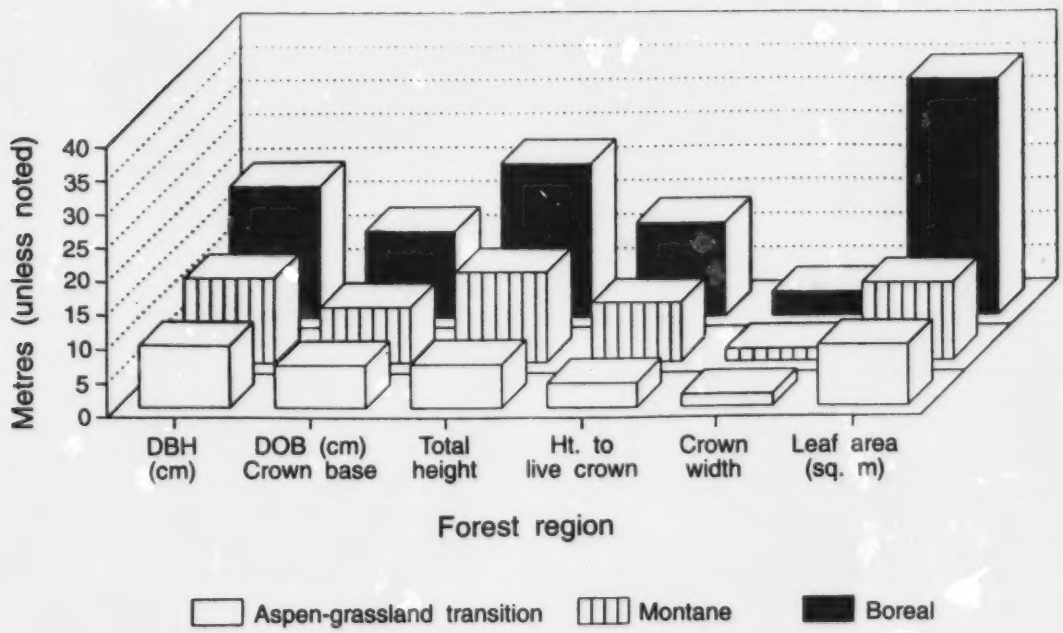

Figure 4. Growth parameters of aspen in different forest regions in Alberta (recalculated from Johnstone and Peterson 1980).

stands might reach maturity, but their productivity and rate of growth would be reduced by moisture stress. Regeneration will suffer from frequent droughts, fires, and vigorous competition from grasses and forbs. The combined effect is that sustained aspen production is not likely to be successful in this area, although aspen may remain present in favorable localities.

PROJECTED MAIN BOREAL

Aspen is now widely distributed within the main boreal zone. The anticipated increase in air temperatures, coupled with a possible slight increase in precipitation, should result in a positive effect on aspen productivity in the central and northern portions of this zone. Higher amounts of radiant energy, a longer growing season, and less extreme winter temperatures should result in faster, more vigorous growth, at least during the present rotation. Aspen can be expected to retain its competitive edge by producing seedlings of both vegetative and seed origin after cutting or fires.

The southern fringe of this zone is expected to be adversely affected by the climate change. Here, the progressively drier climate will cause aspen regeneration to fail on the droughtier soils and on south-facing slopes. Grasses and forbs, better adapted to low levels of soil moisture and frequent droughts, will dominate instead of aspen or conifers. Although good aspen growth will be possible on lower slopes and moister sites, on other sites aspen growth will be slower due to moisture stress and insect and disease infestations of the weakened trees.

A progressively warmer climate will certainly increase the incidence of forest fires throughout the main boreal zone. A dramatic increase in burned area has been observed to accompany the warming and drying trend of the late 1970s and early 1980s (Van Wagner 1988). In 1980 and 1981 records were set and reset with the average burned area varying from a low of 0.9 M ha in 1968 to 4.8 M ha in 1980 and 5.4 M ha in 1981, much of which was in west-central Canada. In 1989 at least 6.4 M ha burned (Stocks, in press), including large areas in Manitoba. The fires may affect the growing aspen stock, but aspen regeneration, especially through suckering, should result in adequate regrowth in the burned aspen or mixedwood stands. Indeed, the rapid early growth of aspen will give it a strong competitive advantage under such highly disturbed conditions.

The rate of change in the main boreal zone will be less obvious than in either of the ecotones. The existing stands, growing at a faster rate than at present, should reach maturity before further changes in the climate will be noticeable. If atmospheric CO_2 accumulation continues beyond the double present levels, however, aspen productivity in the main boreal zone will be progressively negatively affected. Plans beyond the next rotation should include growing short rotation aspen crops and hybrid species mixes in anticipation of this possibility.

PROJECTED NORTHERN ECOTONE

The changed climatic regimes indicate substantially higher temperatures and more precipitation than at present. Aspen already growing in this area should respond with increased growth to the generally warmer climate and longer growing seasons. An increasingly milder climate would also allow aspen to extend its range beyond its current limits, provided other factors do not limit the migration.

Warmer summer temperatures are expected to cause extensive thawing of permafrost. In highly icy permafrost areas this will induce uneven subsidence and mudflows. When stabilized by eventual desiccation, such disturbed surfaces can serve as seedbeds for aspen. Although aspen reproduces readily from suckers, sexual reproduction does take place from seeds produced annually in copious amounts and widely dispersed by wind (McDonough 1985). Paleobotanical studies in the northern Yukon (Delorme et al. 1977) indicated that *Populus* was an early pioneer on lands recently vacated by the continental ice sheet.

It is expected that conditions for aspen growth will improve in the present northern ecotone in response to the milder climate. Aspen may not benefit from the more favorable climate in all of this area, however. A large part of this area is on the Canadian Shield, where the soils are sandy and shallow over bedrock. Aspen

would not grow well on such sites due to poor rooting depth, lack of soil moisture, and low nutrient status. Here, aspen has good growth potential only in valleys and on lower slopes where the soils are deeper and contain more moisture.

CONCLUSIONS

Our confidence in the changes outlined above, which are based on our current understanding of projected global warming and vegetation interactions, is increased by observations of the paleoecological record. Persistent warmer climates during the Holocene, similar to those expected during a 2 × CO_2 scenario, resulted in a large extension of grasslands into the present boreal forests (Ritchie 1976) and a northward displacement of the tree line (Nichols 1976). This indicates that the ecotonal regions of western Canada are sensitive to persistent climate shifts.

If greenhouse gases could be stabilized at the 2 × CO_2 level and the vegetation allowed to reach an equilibrium with the changed climate, the ecological zonation in western Canada would be shifted considerable distances northward (Fig. 5). Aspen would lose some ground in the south, but on the whole would benefit from increased productivity and extended range in the central and northwestern portion.

This presents both a challenge and an opportunity for forestry. The challenge is to recognize the changing ecological conditions in response to the changing environment. The forest manager has to think not only in terms of today's conditions, but also in terms of change that is not likely to occur until today's seedlings reach merchantable size. Past experience at any one site will not necessarily be a reliable guide to the future crop, as the site conditions will change during the life of the crop.

The projected climate change offers an opportunity to maximize aspen production in areas where aspen is expected to benefit from the changing climate. The rapid initial growth of aspen and its ability to reproduce vegetatively make aspen a prime candidate for management under the changing conditions. The introduction of superior clones or hybrids would allow even shorter rotations, making aspen less vulnerable to further unfavorable changes in the climate.

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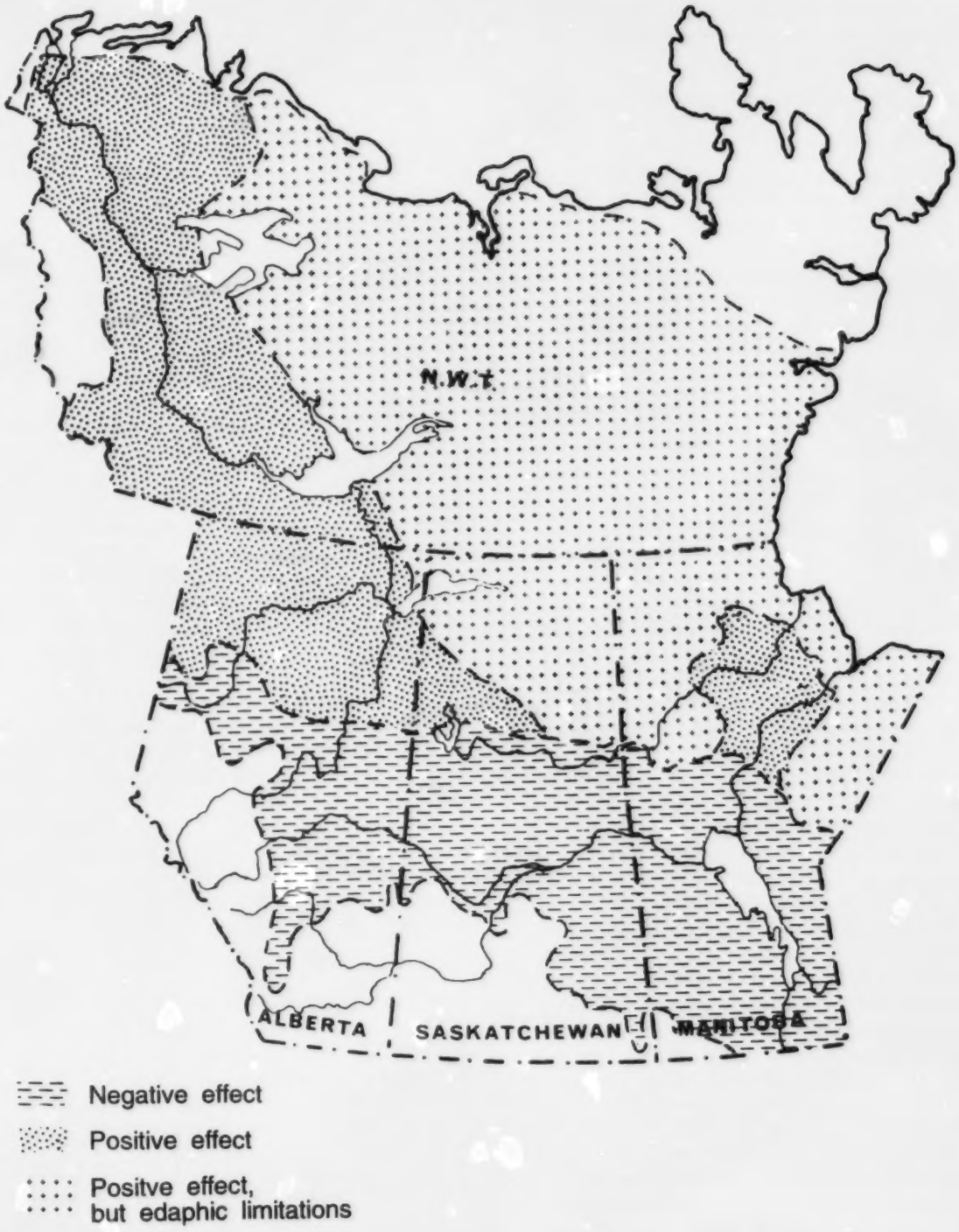

Figure 5. Projected impact of climate change at 2 × CO_2 levels on aspen growth in west-central Canada.

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SUSTAINABILITY OF THE ASPEN RESOURCE

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Edmonton, Alberta

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University of Alberta
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I wish to make some brief comments on the sustainability of aspen in forest ecosystems in relation to the recent expert review panel report on forest management in Alberta (Expert panel on forest management in Alberta 1990) and the broader concepts of sustainable development that we hear so much about.

When I refer to aspen, I include both the deciduous and mixedwood forest ecosystems, because aspen is an important constituent of both. I am convinced that we will be managing the species in both contexts in the future. In addition, mixedwood ecosystems are well suited to the integration of a variety of uses on a forest land base where the public expects such integration.

The report of the expert panel represents a consensus of opinion of four individuals with diverse backgrounds and experience: Bruce Dancik, an academic and forest genetics specialist; Bob Udell, an industrial forest manager and strategic planner; John Stelfox, an Alberta wildlife biologist and consultant with many years of experience; and myself, a researcher with a background in silviculture research and development transfer.

As far as I know, the report has not been suppressed, as was suggested earlier today. We do not consider ourselves infallible, and the recommendations, some 132 in all, are not the modern equivalent of the Ten Commandments. They were derived through lively debate among the authors and through consultation with a wide variety of resource specialists. We hope they provide a basis for ongoing debate and a change for the better in forest ecosystem management in Alberta.

In the report, we adopted a consistent theme of forest ecosystem management that reflects the concepts of sustainable development right down to the operating level, as reflected in world, Canada, and Alberta conservation strategies. These grew out of a variety of documents in which sustainable development has been defined and redefined in recent times. For example: the World Commission on Environment and Development (Brundtand Report) 1987 states that sustainable development is "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." We must modify our approach to "economic growth" by factoring in "environmental consideration." Rees (1990) notes that sustainability in the real world means living on the interest. It recognizes the pathological relationship between environment and economy; the ecology limits to material growth and population growth; and that the economy is a dependent subset of the ecosphere. Sustainable economic activity is limited by the health and productivity of the ecosystem. It states that the harvest rate for renewable resources must be held to average rates of production and not be responsive to ever-increasing market demand, or we will liquidate the ecological capital stock. The Economist (1989) notes that the phrase "sustainable development" has no clear meaning, with arguments ranging from the need to maintain the current stock of natural resources (trees, soil, wildlife, water...) to the suggestion that it does not imply the maintenance of any particular

Brace, L.; Dancik, B. 1991. Sustainability of the aspen resource. *In* S. Navratil and P.B. Chapman, editors. Aspen management for the 21st century. Proceedings of a symposium held November 20-21, 1990, Edmonton, Alberta. For. Can., Northwest Reg, North. For. Cent. and Poplar Counc. Can., Edmonton, Alberta.

mix of human, physical, or natural assets, but that the composition of the asset base will change as development proceeds, through substitution.

This approach fails when substitution is not an option, for example, when dealing with the ozone layer or species extinction.

Evidence that there are many meanings of "sustainable development" is its adoption by wild-eyed preservationists and resource exploiters alike.

Gordon Barkerville (1990), in his address to the National Forestry Forum on Sustainable Development and Forest Management, noted that sustainable development requires three things: a definition of what is to be sustained in both quantity and quality; a forecast of actions needed to achieve sustainability; and a forecast of the timing of these actions, their geographical distribution, and responses to them (feedback).

Some of the things we require in order to ensure aspen sustainability in aspen and mixedwood ecosystems include the following:

1. an understanding of key underlying ecological processes—hydrology, the carbon cycle, nutrient cycles, and ecological limits of productivity (see Zoltai et al. 1990);

2. an adequate inventory of the aspen resource, within an ecological site classification framework linked to key processes and that provides a baseline for assessing management practices aimed at sustained productivity;

3. policies that provide a secure land base on which to produce aspen. Clear management jurisdiction is needed on the land base, and the trade-offs between aspen and conifers and other hardwoods, especially on the mixedwood land base, need to be determined. One must allow for land-base impacts of non-forestry developments like utility corridors, oil and gas, and coal mining;

4. realistic stocking and growth standards for aspen in pure and mixed stands, in terms of ecological units;

5. monitoring, feedback, and interpretation of impacts of forestry operations such as roads, harvesting, and site preparation upon aspen productivity within the boundaries of the secured land base. This includes adoption of pre-harvest silviculture prescriptions (PHSPs) or similar tools and tools recognizing the implications of maximum allowable site degradation (MASD) as a result of forestry operations as is currently done in B.C. (B.C. Silviculture Regulation 147/88, O.C. 593/88);

6. assessing the probability of occurrence and impacts of insects, diseases, fire, and mammals upon aspen.

I am sure you will recognize the similarity between these requirements and those listed earlier today by Rick Bonar as necessary for successful integrated resource management (IRM): inventory, planning, implementation, and feedback.

Here is a recap of some key requirements for sustainable aspen and mixedwood ecosystem management.

1. Our approach must be sound, based on an understanding of or at least a concern for ecological processes. Our approach should be adaptive and subject to continuous review in the light of new scientific information, technology, and social factors. In this regard, although there is a large body of aspen knowledge, as noted by many of our symposium contributors, there are also many gaps, and we must be prepared to act in a conservative manner, and on principle, where we are ignorant of facts. For example, we should take the point of view that it is better to prevent environmental impacts of questionable effect than to try to mitigate those effects after damage is done.

2. Suitable tools are needed, including decision support systems (DSSs) and geographic information systems (GISs), as demonstrated in principle and in some initial applications in the symposium poster area.

3. Effective implementation must include adequate guidelines, ground rules, and training to get it done well. Demonstrations from which we can all learn are needed.

4. Adequate monitoring and feedback will facilitate change and adaptation.

5. Continuing communications with and education of participants involved in the solution to the IRM puzzle is required. Yes, we need more public involvement.

Although we could spend time debating inadequacies in our understanding of the requirements for sustainable development, we must move away from the abstract and begin the process. Aspen provides a wonderful opportunity for foresters to practice sustainable development since it is known to be sustained in unmanaged fire-driven ecosystems, and we know enough about management-related effects to begin the effort. The result of our work will be etched in the landscape for all to see, and many people are watching, including the land owner! The stakes are high and include the professional credibility, not just of foresters, but of all resource management professionals.

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POSTER SESSION ABSTRACTS

PREDICTING FIRE BEHAVIOR IN CANADA'S ASPEN FORESTS

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The Canadian Forest Fire Behavior Prediction (FBP) System enables fire managers to make quantitative estimates of the major physical characteristics associated with free-burning fires (i.e., spread rate and distance, fuel consumption, frontal intensity, elliptical fire size and shape) on the basis of fuel, weather, and topographic conditions. FBP System fuel type D-1 (leafless aspen) is typified by pure, semimature trembling aspen stands prior to "green-up" in the spring or following leaf fall and curing of lesser vegetation in autumn. Although the FBP System was designed primarily as a guide in wildfire protection programs, it can, with judicious use, also be applied to prescribed fire management issues.

INTEGRATION OF WILDLIFE HABITAT AND TIMBER MANAGEMENT

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University of Alberta
Edmonton, Alberta

R. Bonar and D. Walker
Weldwood of Canada Ltd.
Hinton Division
Hinton, Alberta

R. Quinlan
Alberta Forestry, Lands and Wildlife
Edmonton, Alberta

A. Sikora
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Edmonton, Alberta

Habitat models representing all species on Weldwood's Forest Management Area in Hinton, Alberta, are linked to the timber supply model in a way that helps to predict current and future habitat supply. Changes in harvesting policy can be reflected directly in modified habitat supplies and allowable cuts. Poplar and mixed poplar stands make up significant portions of the total wildlife habitat.

DEVELOPING A DECISION SUPPORT SYSTEM FOR ASPEN STAND MANAGEMENT IN WESTERN CANADA

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A decision support system (DSS) that synthesizes fragmented research results, operational knowledge, and heuristic rules into an integrated knowledge base is currently being developed at the Northern Forestry Centre. The system will support decision making on harvesting, regeneration, tending, yield, and product forecasting at the stand level and will provide financial analysis. Interfacing with GIS and incorporating knowledge bases on wildlife, ecological site classification, and inventory will link the aspen DSS to the mixedwood management DSS. This will facilitate decision making at the forest level.

DECISION SUPPORT FOR ASPEN/MIXEDWOOD MANAGEMENT

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The Forest Resources group at the Northern Forestry Centre has initiated the development of mixedwood management decision support systems (DSS). These computerized decision support systems will encompass an expert systems framework for use by forest land managers in the western and northern region. Progress to date includes development of broad concepts and initiation of a prototype aspen DSS (projected completion, 1992). Once this system has been completed, softwood and mixedwood components will be included. Over 150 sample plots have been established in two pilot areas west of Whitecourt and southeast of Grande Prairie, Alberta, for DSS validation (testing site classification predictions within a geographic information system).

PRE-HARVEST GIRDLING OF ASPEN TO CONTROL POST-HARVEST SPROUTING

B. Grainger
Brinkman and Associates Reforestation Ltd.
New Westminster, British Columbia

The Lil Beaver power girdler is being used to girdle aspen 2-3 years before harvest. Theory indicates that harvesting after the root system has died will eliminate the need for subsequent treatments to meet stocking standards on conifer and mixedwood sites. Field trials are being carried out and monitored in various biogeoclimatic zones in British Columbia and Alberta to study biological- and cost-effectiveness. Operational costs are from $125 to $300 per hectare. Permanent plots are installed, and post-harvest sprouting will be monitored.

USING FORCYTE-11 TO EXAMINE THE MEDIUM AND LONG-TERM EFFECTS OF MIXEDWOOD MANAGEMENT IN WESTERN CANADA

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Increased commercial use of boreal forest hardwoods has intensified interest in mixedwood management of trembling aspen (*Populus tremuloides* Michx.) and white spruce (*Picea glauca* Moench [Voss]) in western Canada. New silvicultural prescriptions and harvest regimes for these two species must be examined for the medium- and long-term sustainability of yield and changes in site quality. The FORCYTE-11 ecosystem model uses empirical data combined with process simulation to predict the ecological and economic consequences of a range of forest management practices.

CLASSIFICATION AND MEASUREMENT OF ASPEN DECAY AND STAIN IN ALBERTA

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The major types of aspen (*Populus tremuloides* Michx.) decay and stain that occur in Alberta are described and illustrated. Internal stem defects are classified into five new categories on the basis of color and hardness. External indicators of decay and stain and other conspicuous stem abnormalities of aspen are described and illustrated. The use of a prototype wood-hardness measuring device is outlined, and sampling and measurement guidelines are presented.

THE NONFORESTED PRODUCTIVE LAND CLASSIFICATION

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In Saskatchewan, the need for a more detailed forest data base on artificially or naturally disturbed lands resulted in the development of a new forest survey method called the Nonforested Productive Land Classification (NFPLC) (also referred to as Productive Forest Land Depletion Classification). The NFPLC utilizes low-level aerial surveys supplemented by ground control surveys to evaluate the post-disturbance regeneration of hardwood, softwood, and mixedwood forests.

FINANCIAL IMPLICATIONS OF SOME HARVESTING OPTIONS IN OVERMATURE ASPEN STANDS IN ALBERTA

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Western Canada's huge aspen resource (with AAC in northwestern B.C. of 3.5 million m^3, Alberta 8.4 million m^3, Saskatchewan 2.6 million m^3, and Manitoba 1.8 million m^3) has recently come into its own. In Alberta, nearly 6 million m^3 of aspen will be harvested annually by the mid 1990s. The simplicity of aspen silviculture notwithstanding, the manager is faced at least with two important decisions: 1) what to do with the overabundant overmature stands; 2) what densities to grow the new stands (i.e., to thin or not to thin). We present a financial evaluation of overmature stand harvesting options.

QUANTIFYING THE PHYSICAL ASPECTS AND IMPACT OF FIRE IN ASPEN ECOSYSTEMS

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This poster-paper very briefly summarizes the result of a study dealing with the characteristics of fire behavior and the biological effects of fire on woody vegetation in six aspen northern hardwood stands. Burning conditions were described in terms of the Canadian system of forest fire danger rating. The response of trees and shrubs was surveyed at the end of the first growing season following fire. A prescription for prescribed burning to improve wildlife habitat is presented.

SITE CLASSIFICATION FOR ASPEN AT FORT A LA CORN, SASKATCHEWAN

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Predictions of mean annual increment and site index from texture and drainage classes on provincial forestry maps were tested against field measurements. Actual productivity of aspen stands averaged less than predictions, reflecting the location of the area at the southern margin of the boreal forest. Grouping of field data by landform and drainage class accounted for more of the variation in site index than grouping by texture and drainage. Based on these findings, a classification of aspen ecosites, with local predictions of site index, was developed for the study area.

REGIONAL WHITE SPRUCE AND ASPEN STAND GROWTH: A LONG-TERM EVALUATION OF TREE AND STAND DEVELOPMENT UNDER CONTROLLED DENSITIES FOR BOTH SPRUCE AND ASPEN. WESTERN BOREAL GROWTH AND YIELD COOPERATIVE—A WESBOGY STUDY

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The objectives of this study are 1) to advance the understanding of mixed species plantations of white spruce and aspen; 2) to assess total and species productivity at various density levels; 3) to quantify growth and mortality relationships; and 4) to model dynamics and yield of various plantation mixtures of these species. The design is a randomized block, where each company or agency sets up and maintains one block. Each block consists of two installations, one on a superior site and one on a medium site. Effectively this means that the experiment for each agency (block) can be analyzed separately or in combination with other installations. Each installation consists of two replications of a series of 14 plots.

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